Folks,

RADAR OPERATORS'S MANUAL, RADAR BULLETIN NO. 3, (RADTHREE), April 1945 was created near the end of WW II. It describes the peak of WW II US radar technology.

In this online version of the manual we have attempted to keep the flavor of the original layout while taking advantage of the Web's universal accessibility. Different browsers and fonts will cause the text to move, but the text will remain roughly where it is in the original manual. In addition to errors we have attempted to preserve from the original this text was captured by optical character recognition. This process creates errors that are compounded while encoding for the Web.

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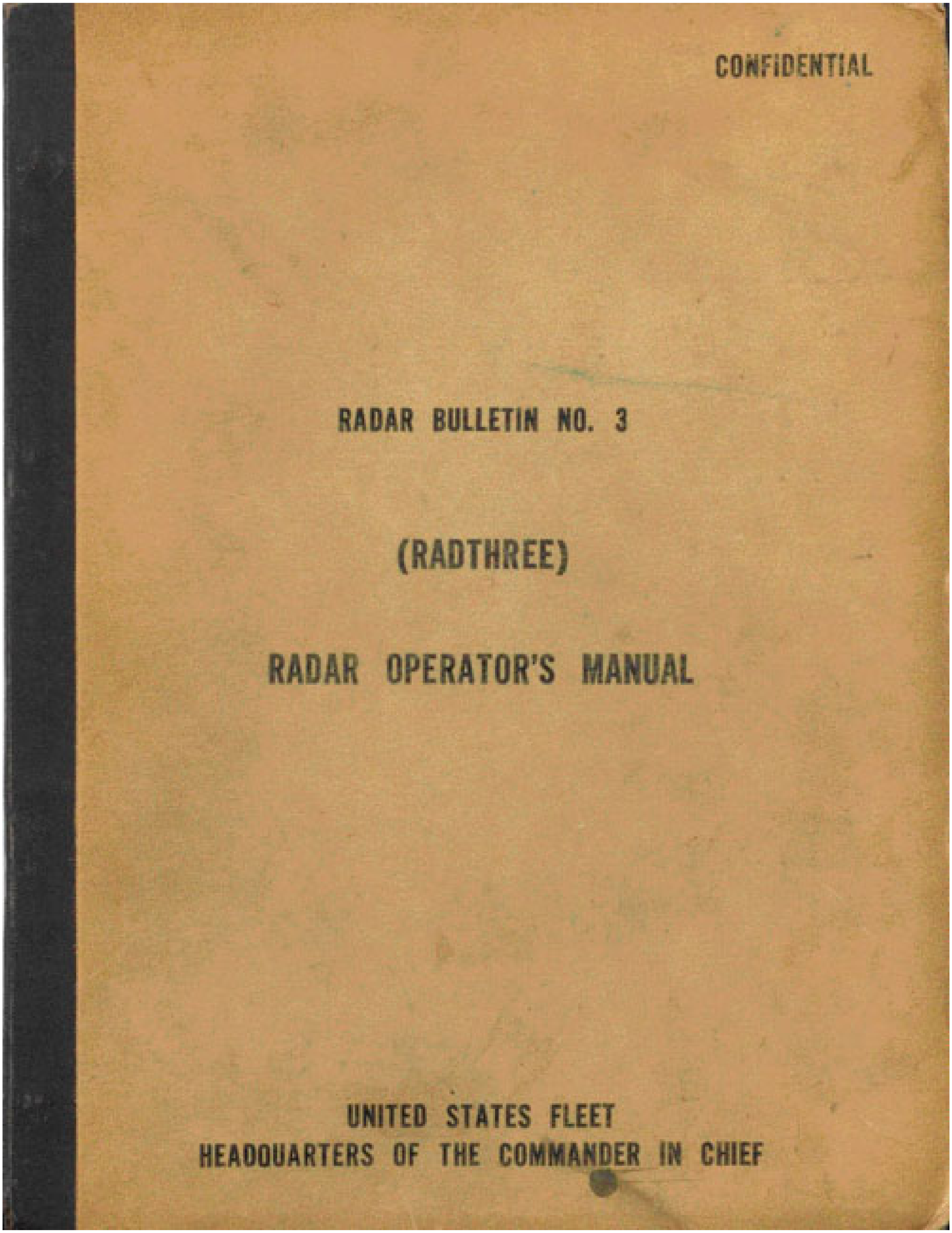

UNITED STATES FLEET
HEADQUARTERS OF THE COMMANDER IN CHIEF
NAVY DEPARTMENT
WASHINGTON 25, D. C.

April 1945.

FF1 /S67-5
Serial: 01090

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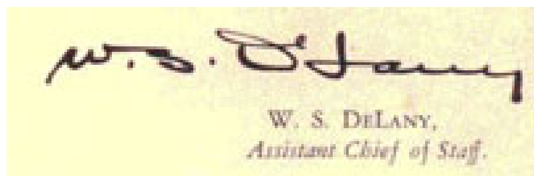

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Assistant Chief of Staff.

UNITED STATES FLEET
HEADQUARTERS OF THE COMMANDER IN CHIEF
NAVY DEPARTMENT
WASHINGTON 25, D. C.

5 August 1944

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C. M. COOKE, JR.,
Chief of Staff.

CHANGE NO. 1

TABLE OF CONTENTS

CHANGE NO. 1

FOREWORD

NOTE: You are being entrusted with vital military secret when you learn about radar. It is imperative that you keep what you learn about the operation, performance and functions of all radar a secret. Stop and consider what radar does for you in guarding your hip and in protecting your life and the lives of your shipmates. This miracle weapon is largely on our side. That is where it will remain if security functions

of hours of operation answers such questions as "When should automatic control of antenna rotation be used, and when manual?" When should the PPI scope be used, and when is the "A" scope the preferred unit?" It has been found that many operators who received their training before the development of the PPI scope are not getting maximum benefit from present-day radar because they have never learned the full advantages of the PPI and the proper method of using it.

Another section of Part 3 is devoted to a general discussion of pipology, the art of interpreting the various types of pips that appear on radar scopes. This is not an exact science, but an art in which the operator cannot be expected to attain absolute perfection. It is probably the most difficult, and yet most interesting phase of radar operation. The basic

properly. KEEP WHAT YOU LEARN TO YOURSELF!

This manual has been prepared in response to repeated requests for a summarization of radar operating information written in non-technical terms, to be used by ships and other units in setting up training programs of their own for officers and men. In its preparation, care has been taken to avoid terms that are not readily understandable. It has been the purpose of the writers to use simple language and familiar illustrations so that the contents will be within the comprehension of the untrained seaman.

Part I is a simplified course in general radar principles presented in a fashion similar to that used at radar operator's schools. It is given as a fundamental course prior to instruction on the radar equipment, for it has been found that the one who knows the reasons for tome of the phenomena encountered in operation develops into a better and more resourceful operator. It is therefore recommended, that in setting up a training program, all operators be instructed in radar principles.

Part 2 is a presentation of the principles and employment of IFF (Identification, Friend or Foe). It points out some of the principles and finer points are discussed and illustrated to give the operator the benefit of the experience of others, so that he need not start at the "bottom of the ladder". Even so, proficiency comes only after the operator has made many estimates, good and poor. and has been encouraged and corrected by a patient topside observer who can see the targets under consideration.

The third section of Part 3 is a discussion of both mechanical and electronic jamming, with stress on operational counter-measures. It is vitally important that all radar personnel understand this section thoroughly.

Individual radar sets are carefully illustrated and discussed in Part 4. Correct step-by-step procedure in turning on and off, calibrating, tuning and operating each set is presented in this chapter. The various uses of each set are explained. Anti-jamming techniques are discussed briefly. Ways to recognize improper operation and inferior performance are described, along with suggestions for correcting these faults. Finally, results to be expected from each are given, so that the efficiency of radars aboard ships may be compared, and steps taken to correct performance if it is not up to standard.

The new requirements for advancement in rating as a radarman demand a knowledge of plotting and combat information center (CIC) operation. It is therefore necessary that all radar operators become adept plotters as well. At the radar operator's schools,

shortcomings of the IFF currently in use, some of the problems that result, and some methods for solving these problems. A thorough study of this chapter should be made, and all radar personnel are urged to be constantly alert for changes and new developments in this held.

A general discussion of operational techniques is presented in Part 3 (and particularized for each radar in Part 4). In Part 3, many questions that arise in the minds of operators who have not had the opportunity to attend a thoroughgoing, formal course of instruction at a radar school are answered. For instance, the experience representing many hundreds

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FOREWORD

air plotting is taught concurrently with air-search radar; and surface plotting, covering use of the maneuvering board and DRT, is taught along with surface-search radar. Approved methods of plotting air and surface targets from radar information are outlined in RADFOUR and RADFIVE.

Part 5 gives a clear and concise explanation of the relative

of the phones. The radar operator must learn to appreciate the importance of his role in the ships internal communications system, and to make a concerted effort to perfect his technique so that vital time may he saved and misunderstandings minimized.

Because of the urgent need for this manual, it has been rushed to press even though Part 4 is incomplete. For this reason and also because developments in radar equipment and operational techniques are in a state of flux, the manual has been bound in loose-leaf form. From time to time new material will be introduced and old material deleted so that the manual will keep pace with this rapidly changing field. Nevertheless, it will probably he impossible to keep it completely up-to-date at all times. For this reason, even though information presented is believed the best available, it will not he claimed that variation from

motion problem, with a series of practice problems on the maneuvering board. Classes should he organized to study the text and work the sample problems given. Similar test problems should be developed by the CIC officer for additional practice. Constant practice, and only constant practice, will produce the degree of proficiency necessary for good operation in CIC.

A brief section on CIC has been added to acquaint the operator with the basic object and functions of that organization, inasmuch as he will not only work with it but in it.

To answer the need for a standardized phone-talking procedure, Part 6 has been included. In this part there is a discussion of phone circuits, articulation, procedure, standard Navy phraseology, and care

every procedure here outlined should never be permitted. In some instances, to deal with special cases, it may not only be practical but advisable to follow another course of action. Resourcefulness based on knowledge and sound judgment should always he the goal.

Next Part

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Return to the Historic Naval Ships Association home page.

Version 1.00, 3 Sep 05

PART 1

GENERAL RADAR PRINCIPLES

PART 1

GENERAL RADAR PRINCIPLES

INTRODUCTION

The primary purpose of the Navy is to "destroy the enemy," and all the Navy's activities exist only for this purpose. Only those pieces of equipment which will enable it to do this effectively are considered as being of any value.

Closely related to this primary purpose of the Navy is the secondary purpose: self preservation. The ship that fights the most effectively has the best chance of coming safely into home port again. A poorly fought ship may never have another chance to fire its guns.

or smoke or darkness for any great distance, and even on a clear day cannot see far beyond the horizon. Such limitations of visual lookouts have hampered ships for centuries-and still do, unfortunately.

Navy men of the past realized that when an enemy vessel appeared over the horizon or out of a fog bank too little time remained to prepare for battle. So when in search of the enemy, they sent out pickets, a line of the faster, smaller ships in the direction from which the enemy was expected. Then, when the ship farthest ahead saw the enemy rise above his horizon, it signaled the next vessel, and thus the word was passed.

But the picket system did not help much in bad weather or at night. The black of night or a curtain of fog still could hide an enemy's approach. After radio came into general use, pickets or patrol vessels could relay the information beyond the horizon at night or through fog. But even so, the visual lookout of the patrol vessel was handicapped by his limited field of view.

Even if the presence of an enemy were known, battles could not be waged very successfully on dark

Sunken ships do not shoot.

You, as a radar operator, may be wondering how radar helps the ship fire the guns and come safely home again. The purpose of this hook is to clear up that question. Radar performs the old task of finding the enemy but uses new methods. If you understand how this task was performed before the development of radar, it will help you to realize the superiority of radar over any device formerly employed.

Visual detection methods and limitations. Ships have used visual lookouts since the early days of sail. A lookout, however, cannot see through fog

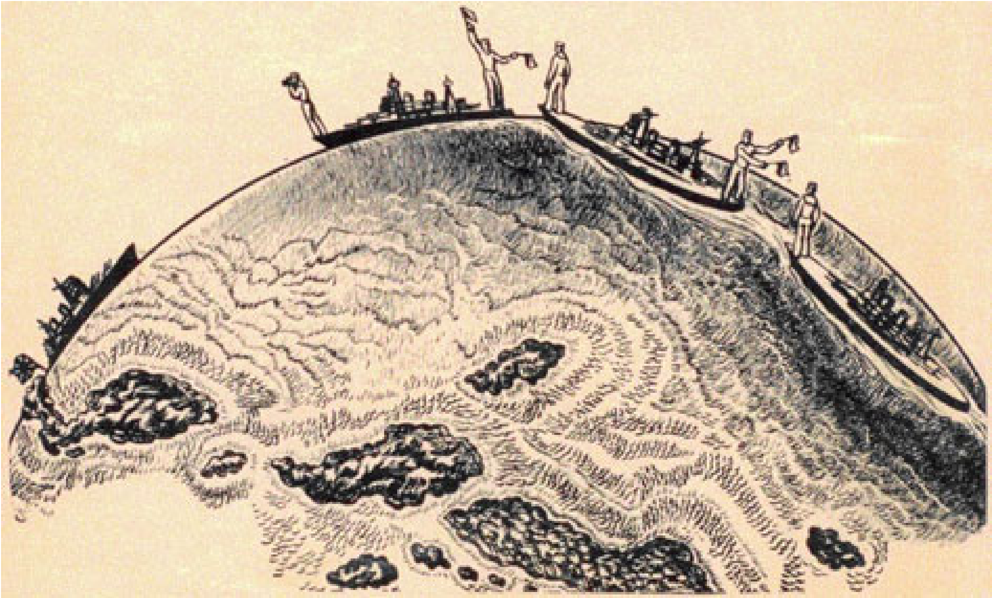

Figure 1-1. Ship to ship communication before radar.

GENERAL RADAR PRINCIPLES

nights because of the difficulty of locating the target. Firing guns blindly in the dark is not effective. Besides being a waste of ammunition it can do harm by betraying your position to the enemy.

Figure 1-2. Indiscriminate firing betrays your position.

Radar overcomes visual limitations.

Radar, generally speaking, can reach out beyond the visual horizon. It can detect through darkness, fog, and smoke as well as through sunshine. You no longer have to wait until the enemy appears over the horizon before you know several facts about him-his presence, number, size, course, and speed. You can be preparing a plan of action before the enemy even knows where you are. Thus, radar enables your ship to "shoot, the guns," even in the dark, and to make hits with the first or second salvo.

Remember that for all practical purposes radar is not affected by visual limitations. It can detect equally well through darkness and smoke, and almost as well through fog. True, it does have a maximum range, a *radar horizon*, but this is usually well beyond the visual horizon. The wider radar horizon gives you earlier warning of the approach of the enemy, affording you precious minutes in which to prepare for battle. Moreover, radar is more than a walking stick for groping in the dark. It actually gives valuable information as to identity, size, and location of objects, which, without it, would be undetected because of distance or poor visibility.

Derivation of word "RADAR".

Let us digress for a minute to study the derivation of the word radar. We know that *radar* uses radio techniques, hence the first two letters RA. We know that it is used in detection and this gives us the letter D. In addition to detection, radar is useful in giving the range of an object. This then gives the last two letters AR, A for and, and R for ranging. If we combine them we have:

RA	Radio equipment for
D	Detection
A	And
R	Ranging

Information given by radar.

Up to this point, we have discussed the function of radar without mentioning just how it operates, other than remarking that it uses radio methods and techniques. Now let us consider what information it furnishes, and how it functions.

Figure 1-3

Radar gives the following information:

1. Presence of an object
2. Bearing.
3. Range.
4. Position angle (angle of elevation) or altitude.
5. Composition.

Radar operation consists of sending out a series of radio frequency (R. F.) pulses from a high power ultra-high-frequency radio transmitter. These pulses are directed into a beam by a directional antenna. When this beam strikes an object in its path, most the R.F. energy will go around the obstruction, and a small amount, depending on the size of the object, will be reflected toward the sending antenna, the transmitter position there is a highly sensitive receiver which will receive or *detect* the small amount returning R.F. energy. From the receiver the

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returning pulse goes to the indicator where it can be observed.

In radar the reflected R.F. energy is called an echo. The *presence of an object* is indicated by the echo appearing on the indicator.

Since the echo returns to the antenna when it is pointed at the object, it can be said that the object must have the same direction, or bearing, as the antenna.

The range to an object can be determined by measuring the time it takes for the pulse to go out from the transmitter to the object and return. To avoid confusion, enough time is provided between pulses to allow an echo to return from the greatest distance at which radar can be expected to function.

operator realize the importance of this super-weapon which you are about to master. The importance of the role which radar is playing in the present war can best be set forth by relating actual instances in which it proved beyond a doubt its superior merit.

Battle of Britain. The Nazi Luftwaffe, intent on bombing England, was itself defeated in part through the use of radar. With it, the British beamed directly on Germany and occupied Europe and saw the enemy planes shortly after they rose from the ground. As the huge armadas approached, the RAF, at that time vastly outnumbered, was always at the right place at the right time to intercept them.

On a Sunday evening, January 17, 1943, the then mighty Luftwaffe appeared in force over London in reprisal for RAE raids on Berlin. There was a bright moon and everything seemed to be in their favor. Much to their surprise, however, the searchlights,

Position angle is the angle above the horizontal at which a plane may be seen. Since protection against enemy aircraft is of great importance, some radars have been adapted to give this position angle as well as range and bearing. This has been accomplished in several Navy sets with sufficient dependability to permit full radar control of AA batteries.

As an operator you can learn to get the information previously mentioned with relatively few hours practice. A superior operator, however, can gain far more information than this. He can determine the composition of the target, including the number and type of units involved. With experience and a reasonable amount of practice you will soon be able to recognize the difference in appearance of the blip (radar indication) representing a surface vessel and that representing an aircraft. Presently, you will be noting differences in blips caused by large ships as compared with those caused by small ones, and can estimate the size of the ship from the size of the blip and the way it behaves. You will also be able to estimate the number of planes or ships producing blips on your screen.

Remember that you will learn how to do these things only by keeping your eyes open and actually trying to learn. The extra information gained can be of vital importance to your ship. You should not be disappointed because you are unable to establish such data the first time that you stand a radar watch, since this ability comes only from skill and familiarity with your set. However, you cannot use inexperience as an excuse for laxity. Excuses will not save your ship; your ability and experience can.

Importance of Radar.

It is imperative that you as a U. S. Navy radar

which previously on similar occasions had scanned the skies in futile search action, now followed the planes with unerring precision. Radar was not only directing the few planes of the RAF to the right spot at the right time, but aiming the searchlights and guns as well.

Without radar, the Air Ministry has said, the Battle of Britain, one of the greatest decisive battles of all history, would have been lost. Radar helped turn the tide of the war. In a sense, it probably saved our entire civilization.

Battle of Midway. Another illustration of radar's effectiveness occurred in the Battle of Midway. A large Japanese force was approaching the island, presumably to attempt occupation. At the island there were several squadrons of land-based bombers. Near by was the carrier Yorktown. Without radar a continuous patrol depending on visible detection would have been necessary. With radar, the enemy was detected while still about a hundred miles distant, and his course plotted. The Japanese were first allowed to close in (thus saving fuel); then the carrier planes and the land-based bombers were sent to the attack. Directed by the large radar stations on the carrier and on Midway, our pilots went straight for their targets. Thus our force, though considerably outnumbered, was able to disperse and defeat the larger Japanese force.

Navy types of radar.

The fundamental principles of all radar sets are alike. However, radar lends itself to many different uses. Each use requires a different application of these principles. In this section, the different types of

GENERAL RADAR PRINCIPLES

Navy radar will be discussed. Every radar operator is to some extent a specialist on certain types of equipment. It is important that he should know his own apparatus particularly well.

Search. Due to the great speeds with which enemy aircraft make their approach, need for detecting them in ample time has become only too evident. A large portion of shipboard radar has been designed for just this purpose. It picks up targets far at sea, giving our own ships sufficient time to prepare for immediate action. Reports from this radar are given at regular intervals to the combat information center (covered later in this book). This makes possible the rapid and accurate plotting of the enemy's course and speed. It is a most valuable aid in sending our own planes aloft to intercept the enemy.

There is also a need for detecting surface targets and securing knowledge of their movements. For this purpose every ship in the U. S. Navy has some type of *surface search* radar aboard. This equipment is not only invaluable for the location of the enemy task force, but is equally important in the location of surfaced submarines (it can detect even their periscopes), or for obtaining positions of ships in convoy.

Both *surface* and *aircraft* search radar are fundamentally alike. However, since each has a different task to perform, special consideration was given to the design of their respective antennas. In the days following the birth of this revolutionary weapon, a group of technical experts devoted a considerable amount of time to the development of the antenna, realizing that therein lay the means of obtaining more accurate beam width comparatively narrow in a horizontal plane, yet large enough in the vertical plane to compensate for the roll of the ship. On the other hand, long wave *aircraft search radar* must have a beam that is wide in the vertical plane because the aircraft targets may be at any angle with respect to the horizon. The horizontal beam width is also large because of a necessary compromise between the need for a narrow beam width, and at the same time a reasonably small antenna.

Engineers and designers were also agreed that aircraft search equipment should have a greater range capability. This was necessary because of the rapid approach of the enemy.

Fire control. During the first year of the war, radar was widely employed as a searching device. Even at that time there were those who thought it could be used equally well in controlling the fire of the ship's guns. Before long, a *fire control radar* was produced: radar that not only gave the direction and distance of the enemy, but also aimed the guns. This particular type of radar has been used extensively and effectively in the vast Pacific in night operations against the Japanese fleet, and it did an equally fine job in silencing the shore batteries at Casablanca.

Shipborne fire control radar, like search gear, is divided into two general classes, namely, anti-ship and anti-aircraft. Here again, the main difference lies in the antenna and beam it emits. An anti-ship fire control antenna must provide a beam which is extremely narrow in the horizontal plane in order to obtain sharp bearing accuracy. This beam is made somewhat wider in the vertical to allow for the roll and pitch of own ship. Otherwise, the beam might go over or fall short of the target. An *anti-aircraft*

target information. For instance, it was found that *surface search radar*, in order to do its job efficiently and effectively, requires an antenna

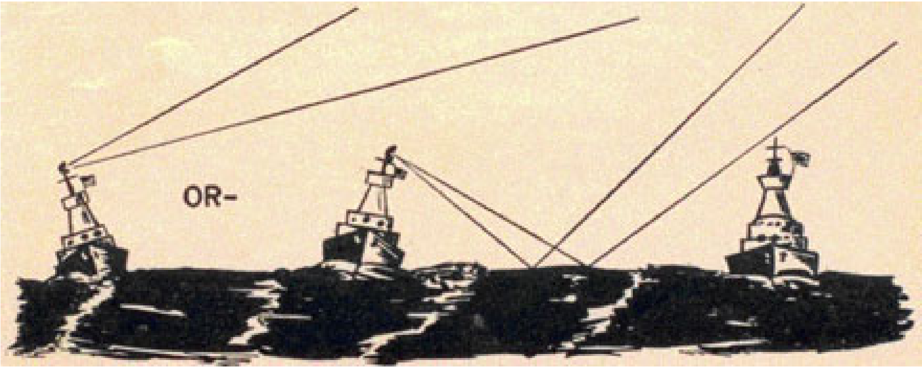

Figure 1-4. Disadvantage of a narrow beam.

fire control antenna must provide a beam that is very narrow in both vertical and horizontal planes; it must also be made so that it will elevate from horizon to zenith (0 degrees to 90 degrees) as well as in any direction on the horizon.

Special. As you progress in your study of radar, you will encounter equipment that is entirely portable and can easily be moved about from one location to another. This apparatus is especially valuable when a beachhead has been established, and it is used to warn against both aircraft and surface targets.

IFF (Identification, Friend or Foe) equipment is a part of the radar in use today. This equipment, rather than being an actual radar, is an aid to radar. It has its own transmitter and receiver and answers the all important question as to whether the target is enemy or friendly.

Navy letter system.

The identification of airborne radar follows the same general rule; i.e., in the case of ASE, "A" is for aircraft, "S" for search, and "E" for the model of the equipment. Other examples of identification letters are the ASB, ASC, ASD, ASG, etc.

Usually, all types of recognition (IFF radar) equipment used with radar, both airborne and shipborne, have the letter B in their designation. Examples of these are the BL or BK models. Following this same system, the airborne model becomes the ABK. The combinations of IFF units are designated Mark IFF radars; i.e., Mark 3 IFF, Mark 4 IFF, etc.

Radars on board ship.

It should be mentioned that there are certain natural combinations of search gear from the standpoint of the functions the sets serve and the ships which carry them. The SG (surface search) and SC or 5K (air search) always go together. These sets are designed for combatant ships of DD size or larger.

In conclusion, it is important that you learn a little about your Navy's way of naming the gear with which you will soon work. There are many radars in the Fleet, each doing its own particular job, each having its own particular name.

First, there are two large divisions of radar, those used for *searching action*, and those used for *fire control*. To distinguish them, their first letter is always "S" if the instrument is for search, and "F" if for fire control.

The second letter in the designation of search radars is usually an indication of the model of one particular type. For instance, a model SC radar is a search radar and is older than an SK. An SO model, on the other hand, is more recent than an SK, all, however, are used for search. When a modification is developed, the Navy uses numbers to designate the new model; i.e., an SC-2 is a modification of an SC.

All models and types of lire-control radar are now named by the Mark system. This system is employed by the Bureau of Ordnance and is used in connection with all gunnery equipment. Some of the earlier models of fire-control equipment were also known by the letter system used on search gear. For example, the Mark-3 radar was also referred to as FC; the Mark-4 as the FD; the Mark-8 as the FH, etc. Later fire-control models are known only by their Mark number such as the Mark-9, Mark-12, Mark-19, etc.

The SL (surface search) and SA (air search) also go together. These sets are designed for ships of the DE class. Another group of sets consists of the SO and SF (the SL can also be included). These sets are all for surface search and one is used on small ships and auxiliaries, such as PT's, PC's, SC's, AK's. and AT's, which do not carry an air search radar. You will be expected to become an expert operator of one of these combinations.

Importance of the radarman.

Since radar does let you "look" through fog and smoke and darkness, you find that it is a great help not only for detecting the enemy, but also for locating your own vessels and for warning you of nearby rocks, islands, icebergs, and similar objects. It is most important for the safety of your ship that you have this information. Of course, if your radar is operated carelessly, you cannot expect it to give good results. If you fail to do your task well, fail to notice instantly the indication of an enemy ship or of a rock, you may well be responsible for the sinking of your own ship. Radar is capable of performing its task well, but only if there is an efficient, alert operator at the controls. Yours is indeed a big responsibility, and the safety of your ship and shipmates depends on how well you do your job. Keep this fact before you every minute you are on duty.

You as a radar operator, are the first aboard to know of the enemy's presence, his strength, and his precise

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location. Before your Captain can begin to maneuver the ship, before the gunnery officer can give the command to fire, *you* must pass on your radar information to them.

The information you receive is of no use whatsoever if you fail to relay to the proper place the

Figure 1-5

information your radar gives you. This equipment is not installed merely for the purpose of satisfying your curiosity. Remember that information, in order to be used effectively, must be received by those with authority to act on it. Your duty is to see that those in command get the information they need. They are depending on you. Remember this: what you tell them or fail to tell them may determine the fate of your ship.

Security.

The more familiar you become with your equipment, the more you will realize the importance of keeping what you know to yourself. You are being entrusted with a vital military secret when you learn about radar. It is imperative that you keep it a secret. Stop and consider what radar does for you in guarding your ship and in helping to protect your life and the lives of your shipmates. This miracle weapon is largely on our side. That is where it will remain if security functions. *Keep what you learn to yourself!*

BASIC PRINCIPLES OF RADAR

Before beginning with the basic principles of radar there are a few terms, symbols, and abbreviations that you should learn in order to help you understand the material that follows.

Definitions.

The word cycle is familiar to most of us, occurring in such expressions as "vicious cycle," "cycle of prosperity," "cycle of life," etc.

The *cycle* is one complete series of events at the end of which conditions are back at the starting point. Beginning with any particular phase or condition, one cycle is completed as soon as it starts repeating itself.

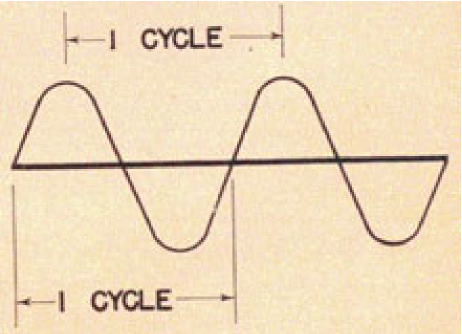


Figure 1-6.

Frequency means only *how often* something is done, as, for example, the frequency of eating, which should be three times a day. The frequency of your heartbeat is about 72 beats per minute. In general, frequency indicates the number of times something occurs in a certain period of time. Frequency in radio is the *number of cycles per second,* or the rate at which the cycles occur.

Since these cycles occur regularly, there must be a definite time required for each cycle. This time is known as the *period*. Remember that it is a measure of *time* required for one cycle to occur. Hence it is reasonable to expect the time for each cycle to decrease when the number of cycles per second increases.

If one second is divided into one hundred equal parts, each part will be one one-hundredth of a second long. The period is 1/100-second when the frequency is 100 c.p.s. (cycles per second). Now, note this carefully: *The period is the same as one divided by the frequency*.

Another term that will help to make our discussion simpler is *wave length*. This is the actual *distance* traveled by the energy while it is completing one cycle.

as expressed before, *distance is proportional to the time*. The *distance* you can go in a certain time is equal to the speed, or *velocity*, multiplied by the *time*. Radio energy too, can travel a certain distance in a given period (i.e., in a definite amount of rime). This distance is called the *wave length*. It is a measure of length, just as feet and inches and yards and miles are measures of length. Using the rule: distance equals velocity multiplied by time, you find that

wave length (distance) = *velocity* (speed) x *period* (time).

Usually, you will not know the period, but this information is not necessary for finding the frequency or wave length. Therefore, a formula which gives the wave length when the period is not known will be better for our purpose. Remember that the period equals 1 divided by the frequency: P = 1/f. Substituting 1/f for its equal P the new formula will read:

wave length = *velocity* x 1/frequency, or WL = V/F

this is the usual formula used in calculating the wave length.

You are familiar with the fact that as long as you travel at a definite speed, you can cover a distance proportional to the time. In other words, if you travel at a speed of 30 miles an hour for one hour you go 30 miles; if you travel for one-half hour, you go only half as far; if you travel fur two hours, you go twice as far, etc. The distance increased with the time or,

Radar energy travels at a velocity (or speed), of 162,000 nautical miles a second. If frequency is 2,000 cycles per second, what is the period, and what, then, is the wave length?

Frequency (f) = 2,000

Therefore the period 1/f = 1/2,000 second = 1,000,000/2,000 microseconds = 500 microseconds.

Abbreviation or symbol	Meaning	Example or equivalent
Kilo	Prefix indicating 1,000	10 Kilocycles = 10,000 cycles
Mega	Prefix indicating 1,000,000	10 Megacycles = 10,000,000 cycles
Micro (u)	Prefix indicating one millionth	10u sec = 10 microseconds 10/1,000,000 sec.
Milli	Prefix indicating one thousandth	1 ma = 1 millampere = 1/1,000 ampere
V,S	Velocity, Speed	
V,S,C	Speed of light or radio waves	300,000,000 meters per sec. 162,000 nautical miles per sec.
˜	Cycle per second	100˜ = 100 cycles per sec.
o	Degree	360º = 360 degrees
F,f	Frequency	
λ (lambda)	Wave length	

GENERAL RADAR PRINCIPLES

Note: 1 second = 1,000,000 microseconds.
The wave length = velocity/frequency.

162,000/2,000 = 81 miles.

1 meter	= 1.09 yards
1 nautical mile	= 2,000 yards (approx.)
1 statute mile	= 1,760 yards

Thus you see that the energy travels 81 miles while it goes through one cycle.

You have learned that radar may be used to determine the range and bearing of a target. *Range* is the distance of the target from you. *Bearing* is the direction of the target.

The table at the bottom of page 1-10 gives the

Principle of pulse reflection.

Now that you know something of the importance of radar, its various types and their uses, and have built up a vocabulary of terms frequently used, let us consider next just how this equipment functions in securing information.

If you understand the principle of sound echoes you

most common symbols and abbreviations which you may encounter in reading the various radar publications,

Frequency code.

Radar equipment operates on many frequencies. some of which are just being explored today. To safeguard this system, operating frequencies or wavelengths are classified and described only by the following code:

Frequency in megacycles	*Code*
0 to 300	P
300 to 1,500	L
1,500 to 5,000	S
5,000 to 10,000	X
10,000 and above	K

Equivalent measurements.

1 inch = 2.54 centimeters
1 yard = 36 inches
1 meter = 100 centimeters
1 meter = 39.37 inches

have mastered one of the basic understandings of radar. Suppose that you are in a canyon and that some distance from you is one of the walls of this canyon. You shout loudly-then wait. What happens? The shout comes back in the form of an echo. Why? It is simply that the sound wave from your voice travel through the air, hit the wall of the canyon, and bounce back. You hear the reflected sound wave. If you want to hear it distinctly you do not shout continuously, but utter one brief sound and then maintain silence until the echo returns.

By shouting for a short interval and then waiting, it is possible for you to shout loudly again the next time. In other words, you are sending out *pulses* of energy of short time duration, thereby making it possible for you to shout at maximum strength without straining your voice.

This is the basic principle of echo ranging: sending out brief pulses of energy and measuring the time it takes them to return.

SENDING ENERGY .... TIME TO RETURN

Figure 1-7 Timing echoes.

RADAR OPERATOR'S MANUAL

Radar also works on the principle of *pulse reflection*. A strong pulse of radio energy is sent out into space from the radar. If there is a target such as a ship or aircraft in the path of this radio energy, some of the radio waves upon striking the target rebound just as sound waves do, and produce an echo. This echo which is not heard, but seen on a special device called the cathode-ray tube, is called a *blip* or a *pip*.

In radar we deal not with sound waves, but with *radio waves*. In shouting, the sound waves are produced by your vocal cords. In radar the radio waves are produced by a unit called the transmitter. This radar transmitter is turned on for a very short period, so short that the time is measured in microseconds (millionths of a second). This short time during which the radar is sending out radio energy is called the *pulse width*, or *pulse duration*. During this short time the transmitter produces a maximum amount of energy.

After the transmitter is turned off, there is a definite amount of time (measured in microseconds) before it is turned on again. This is called the *rest period*. It is during this rest period that the echo returns, if there is a target in the path of the radio waves. This rest period must be long enough to allow time for an echo to return before another pulse of energy is sent out. Accordingly, we have the *pulse width* during which the strong radio signal is sent out into space, and the *rest period* during which time the echo returns. The transmitter is also turned on a certain number of times a second, thus setting up a *pulse repetition rate*.

Bearing determination.

in which you have sent the wave, you know the direction from which the reflected waves come.

In radar the radio waves are concentrated into a narrow beam by a special antenna which will be described later. This narrow beam is much the same as the concentrated beam of light a searchlight sends out. Just as you can point a megaphone or searchlight, you are also able to point the antenna and direct the narrow beam of radio waves in any desired direction. If now you receive an echo while the antenna is pointing in a certain direction, you know the target is in that direction. Radar works the same at night or during bad weather as it does in daytime or during good weather. Accordingly, it is possible to detect a target with radar when it is impossible to see it with optical equipment. By turning the antenna through a complete circle or 360 degrees around you, it is possible to detect any target. You will know the direction or bearing of this target by knowing the direction the antenna is facing.

Range determination by sound.

Detecting the target and knowing its bearing are not enough. You must also know how far it is from you, or the *range* of the target. By knowing both the bearing and range of a target, you locate the target exactly.

The following analogy will help to make the concept of range clear. If a stone is dropped into a pool, a small wave will start out from where the stone hit. This wave spreads out in a circle in all directions. If there is a pole or piling in the pool a short distance from where the stone is dropped, the wave going out will hit the piling and a reflected wave will start back. Assume for the sake of explanation that the

Suppose that there are several large cliffs or walls in different directions from you in a canyon in which you are shouting, and that you desire to receive an echo from one certain cliff. By shouting and sending the sound waves in all directions, you have no way of telling which wall is sending the echo back to you; perhaps they are all sending back a small amount of the energy. By placing a megaphone to your mouth, or by cupping your hands around your mouth, it is possible to *direct* most of the sound waves in any desired direction. If you desire to receive an echo from one certain wall or cliff, you point the megaphone in the direction of that cliff and shout into it. The sound waves are concentrated into a narrow beam, go out, hit the cliff, and are reflected back from the same direction. Since you know the direction

wave is traveling at a speed of one foot per second through the water. If you start a stop watch when the stone hits the water and note how many seconds elapse before the reflected wave returns to the starting point, you can easily tell how far away the piling is. For example, if it takes eight seconds for the wave to go out and return, then the distance traveled is eight feet. The *range*, which is the distance out to the piling, will be one-half of the total distance, or four feet.

A special stop watch could he devised with the face marked off in feet instead of seconds. The dial would read distance instead of time. For example, in place of one, two, three seconds, and so on, the face would read one, two, three feet, etc. Better yet, since we are interested only in the distance *to* the target, the face

of the watch could read one-half foot in place of one second, one foot in place of two seconds, etc. Thus, at the instant the wave returned to the starting place, you could either note where the hand of the stop watch was, or you could stop the watch and read the exact range out to the piling.

What you actually do is measure the elapsed time from the instant the stone hits the water until the reflected wave returns to the starting place. Knowing the speed of the moving wave, you multiply the *time by the speed*. in order to compute the distance. As range is only half the distance traveled, you divide the distance by two and obtain the range. Put in the form of a formula, R = (s x t)/2 where R is range, *s* is speed, and *t* is time.

Let us go back to the example of sound echoing in a canyon. Suppose you want to know how far

(a nautical mile is approximately 2,000 yards): radio waves travel 162,000 nautical miles in one second, or 300,000,000 meters in one second. Knowing the speed of radio waves, it is possible to obtain the range of a target with radar by the same method as that used in the case of sound.

For example, suppose that the transmitter sent out a short pulse of radio energy and that the reflected wave was received after 1,000 microseconds. The distance traveled out to the target and back is 1,000/ *1,000,000 x 162,000 = 162 nautical miles. Referring to the sound analogy, remember that in order to compute the range, the total distance out and back must he divided by two. So also with radar; the total distance must be divided by two. In this case range is 162/2 or 81 nautical miles.

However, the speed of radio waves is much greater than that of sound. Therefore, an ordinary stop

away that cliff (i.e., its range) which sent back the echo is. You need to know that the speed of sound is approximately *1,100 feet per second*, and you also need a watch, or better still, a stopwatch. It is now an easy matter to obtain the range. If, for instance, four seconds pass from the time you shout in this canyon until you receive the echo, you know that the distance traveled by the sound waves out to the cliff and back is 4 x 1,100 feet or 4,400 feet. You know that range is one-half the distance out and back: therefore the range is (4 x 1,000)/2 or 2,200 feet. Since you divided by two, why not divide by two at the start, and make a statement that for *sound*, range equals 550 feet multiplied by time? Thus, it would he 550 x or 2,200 feet.

On your stop watch, you could make a special face to measure range in terms of echoes. Since for sound one second is equal to 550 feet range, in place of one second on the watch have 550 feet, in place of two seconds have 1,100 feet, etc. Thus, whenever the echo returns, it is possible to note where the second hand is at that instant on the face of the watch and to read directly the range of the target.

Range determination by radar.

How does all this fit in with radar? Let us next see how see are able to tell how far away the target is, or how to obtain the range with radar.

Light travels so fast that it is almost instantaneous. Radio waves, electricity, and light, all travel at about the same speed, which is 186,000 land miles per second, or almost seven and one-half times around the earth in one second. Expressing this in *nautical miles*

watch cannot be used. A special timing device is needed to measure such small time intervals as microseconds. This special timing device is called the cathode-ray tube, and on it there is a special time base which takes the place of a second hand on the stop watch. Instead of being marked off in divisions of one, two, three microseconds, etc., this time base can be marked off directly in miles or yards of range.

Summary.

By sending out a very short pulse of energy from a high powered transmitter, and receiving the echo which is called the *pip*, you have *detected* a target. By knowing the direction the antenna is facing, you know the direction or *bearing* of the target. By measuring the time it takes the wave to go out to a target and return, you have a means of obtaining the *range* of the target. If you know the bearing and range of a target, you then know the exact position of this target at any instant. In good weather or bad, in daytime or at night, whether surface craft or aircraft, you are able to establish the desired data. But these are only some of the many things you are able to tell about the target. In the pages which follow you will learn about other information which a good operator can get through the medium of radar.

MAIN PARTS OF A RADAR SYSTEM

In the preceding section you have learned about the principles of radar. This section will deal with

* The 1,000 microseconds must be divided by 1,000,000 to give seconds.

the main parts of a radar set. If you are familiar with the several units that go to make up the radar set you operate, the chances are that you will be able to operate it more skillfully and intelligently. In studying the derivation of the word radar you found that the first two letters ra came from the word radio. You know that in radio there must be a transmitter and antenna system to send our the program; to reproduce the program there must be an antenna system, receiver, and loudspeaker. Likewise in radar the main parts are the transmitter, antenna system, receiver, and indicator which functions in radar in the same manner that the loudspeaker functions in radio.

The transmitter.

Wave length or frequency. To make radio detection and ranging possible, it is necessary at the outset to send out a pulse of radio waves. It is the function of the transmitter to generate the pulse. Since the transmitter creates the pulse, it is the source of the radio energy. There are well defined differences between the radar transmitter and the radio transmitter that operates in the radio station. One of the main differences is in wave bands on which the two types of transmitters operate. Radio stations operate on either the broadcast or the short wave bands, but radar uses the ultra (very) short waves that were previously used only for experimental purposes. Another difference is that radio broadcast transmission is continuous while radar transmission is intermittent.

Duration and power of pulse. An important point to remember about the compact radar transmitter is its ability to send out pulses of radio energy as powerful as, and in many cases more powerful, than the transmissions from the biggest broadcast transmitters. High power is necessary in radio transmissions to carry the broadcasts to the listeners at distant points. In radar very strong

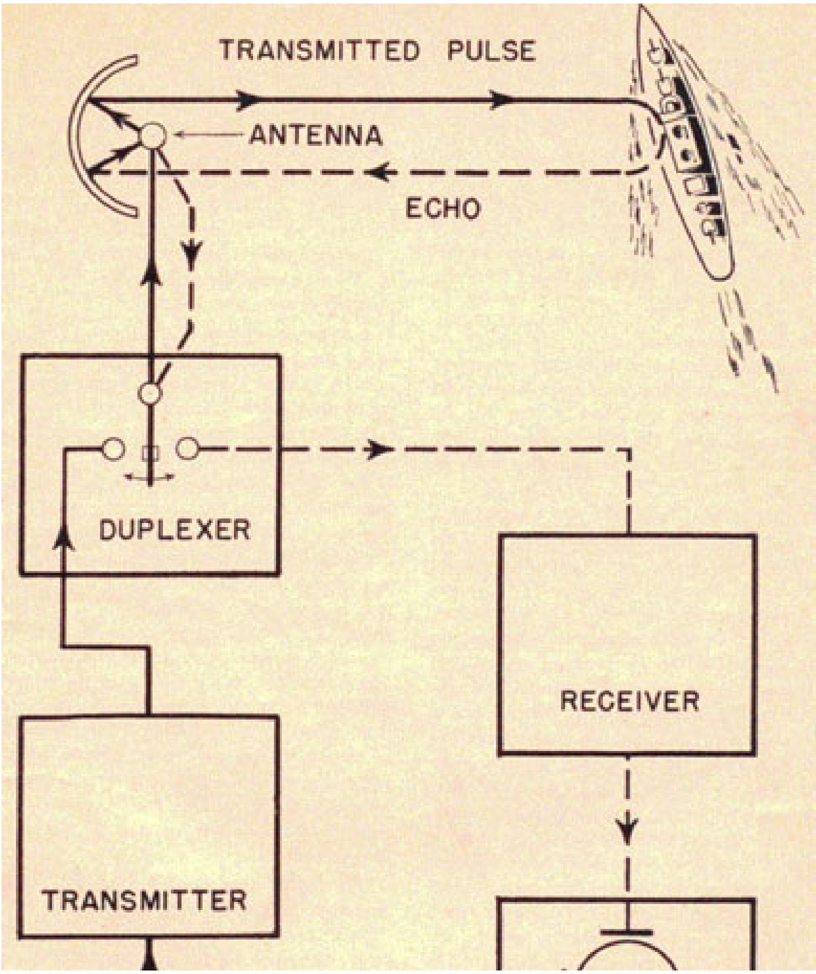
In the section on the principles of radar, the point was stressed that short duration pulses rather than continuous transmission were used in order to provide time for the echo to return. Continuous operation would drown out all reflections or echoes. The actual time the transmitter is sending out radio waves is measured in very small units of time, micro (millionth) seconds. When you read the expression, *pulse width*, banish any and all thought of expressing this value in feet, inches, or meters, because the pulse width is a measurement of the time the transmitter is working. At first, it may be bewildering to consider time reckoned in such small denominations, but later on it will serve as a constant reminder of the importance of speed in all phases of radar.

One advantage that results from the transmitter's working only in brief periods is the long rest or idle period during which sufficient electrical energy can be stored up to provide the extremely high power necessary for the next pulse. Thus the overall or average power output of the transmitter is low, and within the transmitter's capacity. During the brief moment of transmission, considerable heat is generated by the tubes. During the rest period the tubes cool. Should the transmitter be allowed to operate continuously at such high power the unit would be badly damaged or even destroyed by the intense heat. Motor-driven fans or blowers circulate cool air inside the cabinet of the radar set to aid in keeping the temperatures at safe operating levels. The length of the rest period (expressed in microseconds) is dependent upon the *pulse interval* (the time between the beginning of one pulse and the start of the next one) and the *pulse width* (the working time).

Pulse rate. The *keyer unit* performs the task of pulsing the transmitter. The keyer, which will be described later in this section, does exactly what its name implies, it keys the transmitter, turning it on for an instantaneous surge of radio energy for a few

pulses must be emitted in order to get back even a small echo or reflection from the waves striking the target while the rest of the waves continue into space until they die out. Unfortunately, only a minute amount of the energy of the pulse sent out is bounced back. In generating the strong pulses that are needed, high voltages, dangerous to life, are required. Everything possible, however, has been done to make the equipment safe for the operator, so long as certain safety precautions are observed.

microseconds (or even a fraction of a microsecond); then, after the pulse, it turns it off for a comparatively long time until the next pulse. It is during this period while the transmitter is resting that the echoes return from any object that was in the path of the outgoing pulse. The rate at which the keyer pulses the transmitter is the *pulse rate or pulse repetition rate*, which simply means the number of times the transmitter is sending out a pulse of radio waves each second. The keyer operates at a constant rate, spacing the pulses so that the interval between any two is always the same. The length of time of



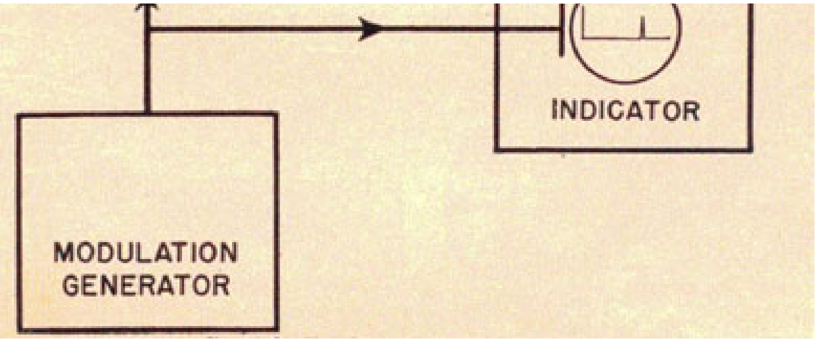


Figure 1-8. Block diagram of a typical radar system.

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the pulse interval is a direct result of the pulse rate. For example, if a transmitter sends 50 pulses at regularly spaced intervals in one second's time, the repetition rate of the unit would be termed *50 cycles per second* (a cycle being one complete operation). To calculate the interval between each pulse, divide one second (one million microseconds) by the pulse rate. 1,000,000/50 = 20,000 microseconds-the pulse interval. (Assume a pulse width of 10 microseconds.) 20,000 microseconds - 10 microseconds = 19,900 microseconds, the rest period. Note the extremely long rest period!

The antenna system.

The antenna system is one of the most important parts of the radar equipment since it radiates the radio frequency energy into space and receives the reflected energy or echo. The antenna system is made up of two parts: (1) the *transmission line*, and (2) the *antenna*.

Transmission line. The purpose of the transmission line is to carry the high frequency energy from the transmitter to the antenna, and to carry the reflected energy from the antenna to the receiver. This transfer of energy must he done

Now the question arises, "Why have two types of transmission lines?" The reason for this is that coaxial lines are more suitable for radars operating below 3,000,000,000 cycles while wave guides are better for radars at and above 3,000,000,000 cycles.

When comparing the coaxial line with the wave guide, the following advantages seem to favor the wave guide: (1) construction is simpler. (2) losses are lower, and (3) power capacity is greater.

The wave guide's principal disadvantage is that unless the frequency is very high, the size of the pipe must be unreasonably large.

Antenna: an emitter of radio waves. In order to utilize the radio energy created by the transmitter pulse, it must be converted into radio waves, which can be shot out to strike any object in the outgoing path. The antenna functions as the converter of the radio energy into radio waves which can be radiated in any desired direction into the atmosphere. To better illustrate this fact, consider the situation resulting when a flashlight is supplied with new batteries but lacks a bulb. Even though the necessary power is available, the means of using it are lacking. As soon as you insert a bulb in the socket and close the switch, the battery energy is put to work and its

with a minimum of loss.

Two types of transmission lines are in general use in radar equipment: the *concentric* or *coaxial line*, and the hollow *wave guide*. The coaxial line consist of one conductor inside another. Both conductors may be tubular, or the outside one may be a hollow tube and the inside a solid conductor. Since the inner conductor must be exactly in the center of the outer conductor, a great number of insulating disks are required. Moisture on these insulators may cause a flash-over or breakdown between the two conductors so it is necessary to keep the line filled with nitrogen or dry air at a pressure of about five pounds per square inch. The wave guide is a hollow metal pipe, the cross section may be rectangular or circular. The rectangular wave guide is most commonly used today.

conversion to light waves results in a beam of light. The transmitter can be likened to the battery-filled flashlight, for it, too, is a source of stored energy-radio energy. The transmitter is inoperative without an antenna for the same reason that the flashlight is inoperative without a bulb. The antenna converts the pulse of radio energy from the transmitter into radio waves, just as the bulb converts the battery energy to light waves.

The fundamental element from which most antennas are built is the half-wave antenna, or *dipole*. This is a metal rod or wire one-half wave length long. Since the velocity of radio waves is constant, 300,000,000 meters per second, the length of a

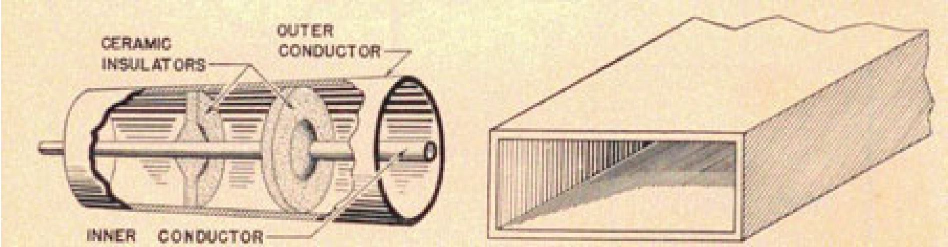


Figure 1-9 Coaxial. Wave-guide.

GENERAL RADAR PRINCIPLES

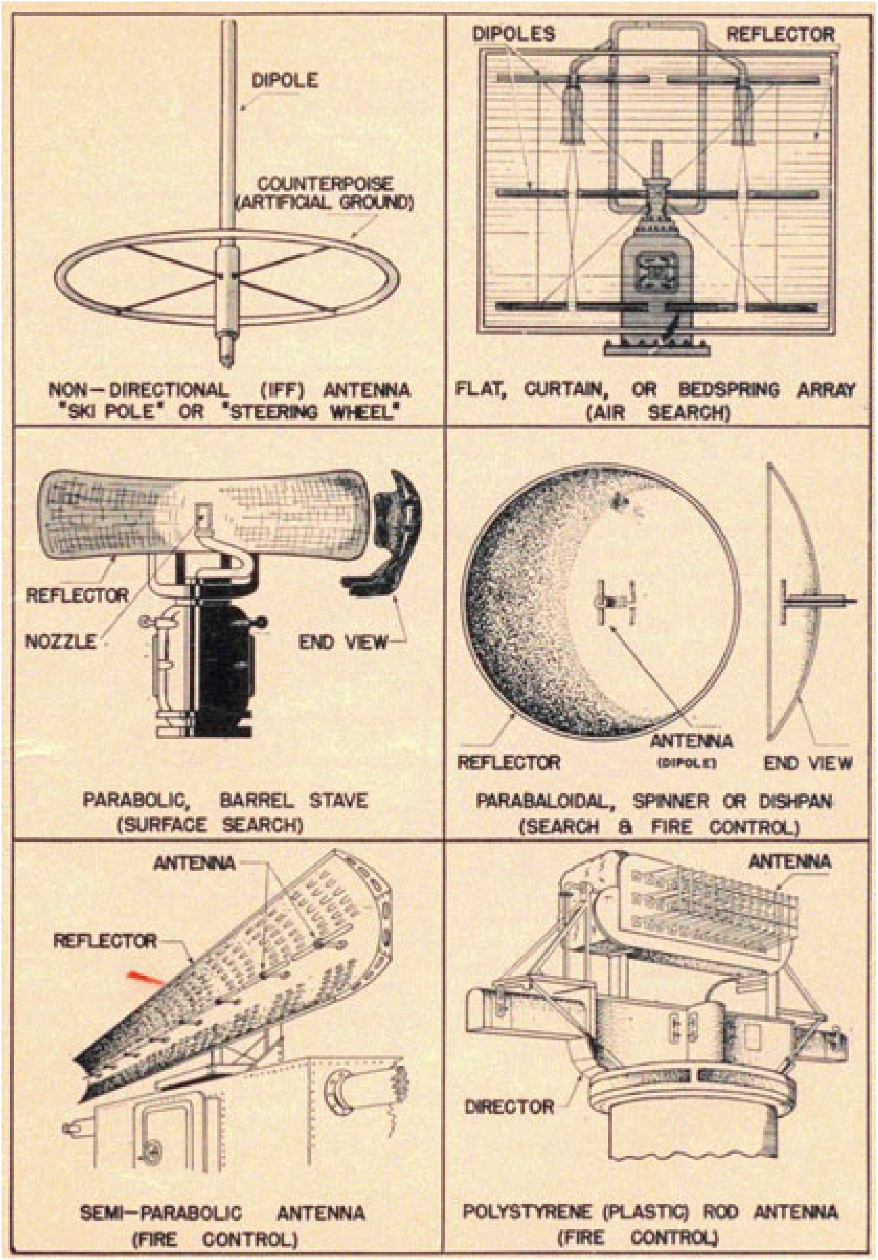

DIPOLE
COUNTERPOISE (ARTIFICIAL GROUND)
NON-DIRECTIONAL (IFF) ANTENNA "SKI POLE" OR "STEERING WHEEL"
DIPOLES
REFLECTOR
FLAT, CURTAIN, OR BEDSPRING ARRAY (AIR SEARCH)
REFLECTOR
NOZZLE
END VIEW
PARABOLIC, BARREL STAVE (SURFACE SEARCH)
REFLECTOR
ANTENNA (DIPOLE)
END VIEW
PARABALOIDAL, SPINNER OR DISHPAN (SEARCH & FIRE CONTROL)
ANTENNA
REFLECTOR
SEMI-PARABOLIC ANTENNA (FIRE CONTROL)
ANTENNA
DIRECTOR
POLYSTYRENE (PLASTIC) ROD ANTENNA (FIRE CONTROL)

Figure 1-10.

dipole gets shorter as the frequency increases. This is another interpretation for the formula; wave length equals the velocity of a radio wave divided by the frequency of a radio wave. Therefore, a given antenna works best at only one frequency.

Non-directional antenna. A single dipole will send its energy out in all directions around itself. The greatest amount of power goes directly outward at right angles to the length of the rod with decreasing amounts of energy out in other directions except in the direction of the rod, where no energy is sent out. Consequently, the side view of the lobe looks like a pair of circles touching the dipole, as shown in figure 1-11.

A target at right angles to this dipole would give a strong echo, while one in the actual direction of the dipole would give a very weak echo (theoretically no echo). One of these dipoles mounted vertically would send a strong signal toward anything around it and on its level. It would give a weaker signal to anything above it. Some of our sets use antennas like this so that any target around them, regardless of its bearing, can be detected. Because the radio waves are going out in all directions, bearing cannot be indicated and only range can be determined.

Directional antenna. A reflector can be used with a radar antenna to make it unidirectional, that is, to cause all the waves to leave the antenna in one direction rather than in two directions. This reflector serves the same purpose, and functions in the same manner as the reflector used in a flashlight. The four most popular types of reflectors are: (1) the flat or "bedspring" type, (2) paraboloidal or "dish pan", (3) parabolic or "barrel stave", and (4) semi-parabolic.

The type of radar antenna using a number of dipoles, called a *curtain array*, or *bedspring* weight and wind resistance, or it may be merely a wire mesh.

If the antenna is wide, you can expect a narrow horizontal lobe because there will be several dipoles horizontally. If there are many dipoles vertically, the

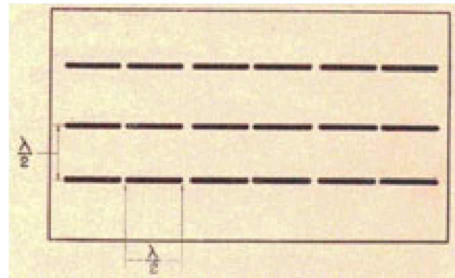


Figure 1-12. Wave lengths.

vertical lobe will be sharp. Of course, the physical size (in feet and inches) of any particular lobe width will depend on the *wave length*. When comparing antenna sizes, be sure to measure them in square wave lengths.

As an example, if you have an antenna like the one shown in figure 1-12 you can measure the area easily by noting that each rod is one-half wave length long, and that each row of rods is one-half wave length

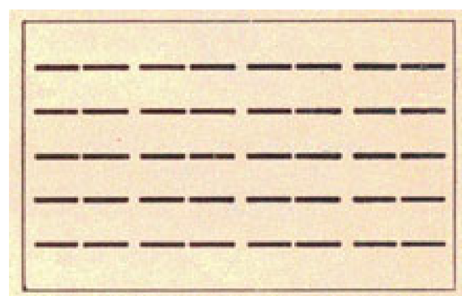


Figure 1-13. Wave lengths.

away from the next. This antenna, then, is three wave lengths broad, one wave length high, and has an area of three square wave lengths.

array, has a metal screen reflector. The dipoles are a definite distance forward of the screen. *The more dipoles used, the sharper the beam*. However, the energy is strongest in a direction approximately at right angles to the screen. The metal reflector is perforated to reduce

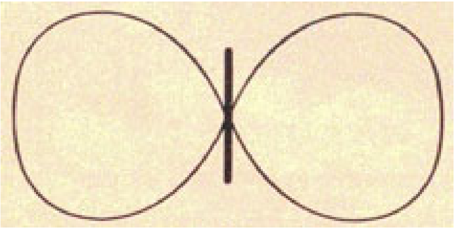


Figure 1-11. Dipole and radiation pattern.

The antenna in figure 1-13, though physically smaller, is four wave lengths wide, two wave lengths high, and has an area of eight square wave lengths-almost three times as great as the previous example.

As a general rule, a sharp vertical lobe is not desirable for search sets because the lobe might shoot over the target and miss it as the ship rolls. If this happened, an echo would he reflected from the target only occasionally, instead of almost every time the

antenna completes a rotation. To avoid this, only a few dipoles are stacked vertically. Remember that the greater the horizontal dimension of the antenna (when measured in wave lengths), the sharper the horizontal lobe; the greater the vertical dimension of the antenna, the sharper the vertical lobe.

Fire-control sets must give accurate bearings, and (if used to control antiaircraft fire) accurate position angles. By reducing the wave length (increasing the frequency), the antenna necessary for this bearing accuracy can be reduced until its size is physically practical. If, also, the reflector is bent into a *semi-parabola*, the sharpness of the vertical lobe can he increased. From the side, this antenna has the appearance of a "V" with a rounded bottom, the "V" being on its side with the wide opening toward the target.

This antenna is not entirely satisfactory for antiaircraft fire control. Being a wide antenna (in wave lengths), it gives satisfactory bearing accuracy, but lacks sufficient position angle accuracy for AA gun laying. To increase this

has been increased. The antenna shape is shown in figure 1-14

As you go to higher frequencies, dipoles and curtains are of less concern. Reflectors of the type used with searchlights can be employed. This is due to the fact that radio waves at the higher radar frequencies behave much like light.

Paraboloidal reflectors, bowl-shaped, are usually called "dishpan" reflectors, or "spinners". They are used for surface-search and some air-search and fire-control sets. Their hearing accuracy depends on the diameter of the spinner measured in wave lengths (the unit of measure used for other types of antennas).

Since this type of antenna produces a "pencil" beam, the beam is as narrow in the vertical plane as it is in the horizontal, which for some types of radar necessitates a helical search (a spiral search, changing the position angle as well as the bearing angle).

accuracy, a modification has been made. In effect, two of these semi-parabolic antennas have been fastened together, one atop the other. In this way, the sharpness of the vertical lobe

On some sets, a sharp, vertical lobe is a definite disadvantage. If a large spinner is used (for good bearing accuracy), the vertical lobe may be too narrow. To increase the vertical beam width, the rep and the bottom parts of the spinner are cut off, which reduces the vertical size of the spinner without reducing the

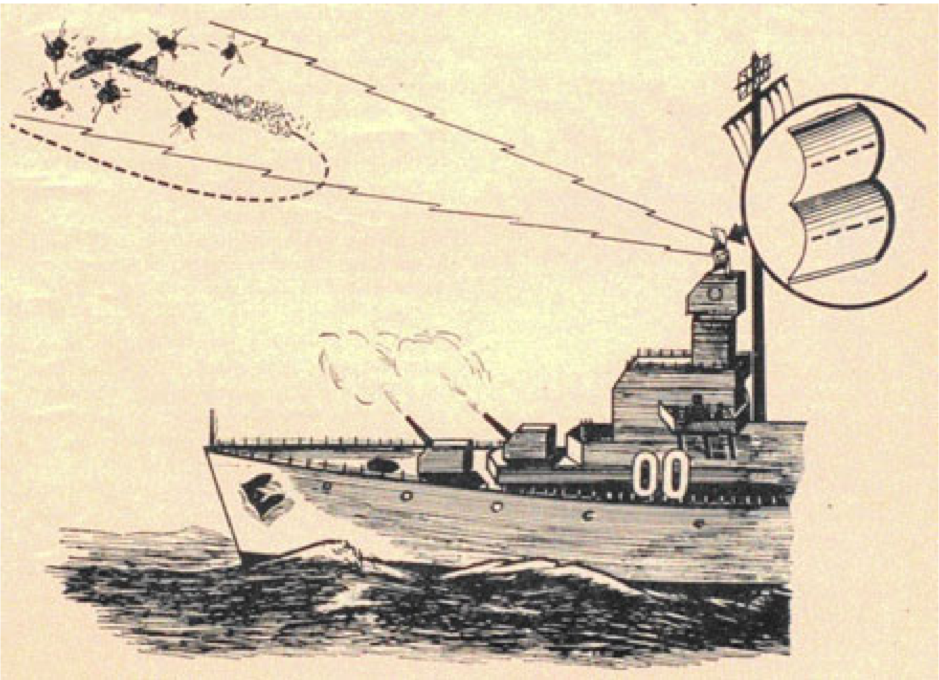


Figure 1-14. Mark 4 antenna.

width, thus increasing the width of the vertical lobe without affecting the horizontal beam width. This type is called the parabolic reflector and, since it resembles a barrel stave, is also known as a barrel slate reflector. Many of our surface search radar sets use this antenna.

Another type of antenna involves an entirely different principle. Tapered plastic rods about three feet long are used, and the energy comes out along the full length of a given rod. A rod by itself will produce a beam about 30 degrees wide. By placing 14 of them side by side, the beam is narrowed to 2 degrees. Three vertical rows are used to narrow the beam to 6 degrees in the vertical plane. When these rods are energized at different times, the lobe goes out to one side-toward the side which received the energy last. Constantly changing the amount of delay causes the lobe to move steadily from 15 degrees to the left of the center line to 15 degrees to the right in 1/10 of a second. The great advantage of this system is that 30 degrees can be seen

reflectors, which give narrow beam widths, presenting better hearing accuracy.

4. The wave length is the unit used in rating antenna size.

How does radar determine bearing?

You have already learned how radar detects the presence of a target and determines range. In this section you will discover just how it establishes the direction, or *bearing and position angle*.

at once, with the accuracy of a 2 degrees beam (similar to television scanning). This permits accurate spotting in both range and deflection. Such an antenna, however, is extremely heavy and complicated.

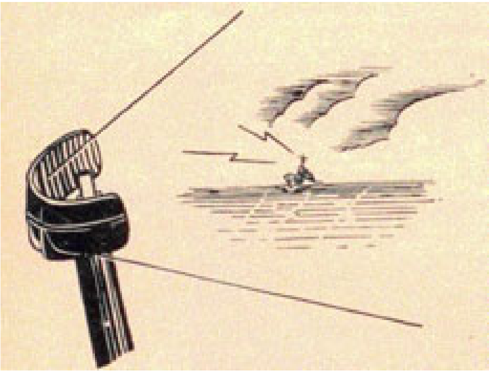


Figure 1-15. Parabolic or barrel stave antenna.

The foregoing discussion of antennas has avoided technical treatment of the subject because for purposes of this handbook only general ideas are needed. It will he helpful to keep the following in mind:

1. The antenna size, in wave lengths, determines the size and shape of the lobe.

2. A *wide* antenna gives a narrow, sharp horizontal lobe, while a *narrow antenna* produces a broad horizontal lobe and poor bearing accuracy.

3. Use of high frequencies permits use of parabolic

When you shout in the direction of a cliff or big building you hear an echo, but when there is no cliff or building to reflect the energy there is no echo. If the radar energy, like sound, is sent out in one general direction, you can tell approximately the direction of an object by simply observing the direction from which the echo returns. By knowing this direction, you know the target's direction since it is the same.

When you shout, the sound as you know, does not go only straight out, but can also he heard to either side of the direction you are facing. The degree to which the energy is scattered will determine how accurately you can judge from the echo whether or not you are facing the cliff. If the sound energy is scattered over a wide angle, perhaps you can receive an echo when you are facing, and shouting, in a direction far off to one side of the target. A small amount of the energy goes off in the direction of the target, and will he reflected as an echo, but it will be a weak echo.

You are probably wondering now how you can tell whether you are getting the echo back from the direction you are facing, rather than from a direction off to one side? The answer to this is that you get the largest echo when you are facing the target directly.

Concept of lobe. Your radar set sends out its energy like sound in a general direction, but with some scattering. You receive radar echoes from a target even if you are not pointing the antenna in the exact direction thereof. But, as in the case of sound, you get the strongest echo when you are directly on the target.

Since you get the strongest echo from an object when the antenna is pointed directly at it, you can reasonably expect to locate a small target in that direction more easily than in any other direction. Likewise, you can detect an echo from a ship at a greater range in the direction the antenna is pointing than in any other direction. It is logical to expect that a ship will reflect a stronger echo when it is only slightly off the antenna hearing than when it is considerably

off the antenna hearing for if a ship lies to one side of the antenna bearing it cannot give as strong an echo as one directly on the antenna bearing, unless it happens to be nearer or larger.

In fact, if a ship sails around your antenna hearing in such a way as to always produce the same strength echo, it will follow the path shown in figure 1-16. This shape is called a *lobe*, and is actually a representation of the range at which you can get an echo of any particular size in any direction from the antenna. It represents approximately the amount of power sent out in any direction. Figure 1-19 shows how great a change in echo height results simply from turning the antenna around, sweeping the lobe past the target.

"E" units. Referring to the actual *height* of the echo in inches is of little value because you can increase or decrease the height of the echo at will merely by varying the gain control. Even a weak signal can easily be "blown up" in this manner until it approaches saturation, but this increase may not help because of the corresponding increase in grass height.

Grass is a disturbance on the cathode, ray tube (C.R.T.) screen, caused by noise in the tubes, static, etc. It shows up as a fuzzy, jumpy fur along the time base on "A" and "R" scopes, and as many small, bright spots (sometimes called *snow*) on the B and PPI scopes. It is always present to some degree, and pips smaller than the grass are very difficult to find. The grass seems to wave just as actual grass does, and may cover the pip. The height of this grass can be controlled by the receiver sensitivity (or *gain*) control low sensitivity means low grass height and high sensitivity means a large amount of grass. You know that the pip height can he made larger by increasing the gain, and smaller by reducing the gain. Since both the pip height and the grass height vary together, the pip size can he compared to the height of the grass for this discussion. The comparison is made in units.

The "E" unit system of discussing echo strength is standard in the Navy. It is a convenient system to use; by providing common terms in which to discuss the strength of echoes confusion and misunderstanding are reduced. A small pip about the same height as the grass is an E-1 echo. It will always he difficult to detect, and only a wide-awake operator will notice it. An echo of this strength will probably he overlooked on a PPI scope by even the very best operator. That is the main reason that an operator should not devote all his attention to the PPI scope.

The complete E system includes five values: E-1, E-2, E-3, E-4, and E-5. E-1, as is indicated above, includes those signals whose ratio of signal to noise, or of pip height to grass height is one to one (i.e., the pip and grass are the same height). An E-2 echo is an echo whose pip is twice as high as the grass. An E-3 echo is one producing a pip four times as high as the grass. If the pip is eight times as tall as the grass, we say we have an E-4 echo. An exceptionally great echo reaching saturation, or 16 times, or more the height of the grass, is spoken of as an E-5 echo.

An E-1 echo is *very weak*, an E-2 echo is *weak*, and F-3 echo is *good*, and E-4 echo is *strong*, and an E-5 echo is *very strong*. The F-5 echoes are the echoes we get from large, nearby targets.

The E-number system enables you to report echo strength in a definite way. You can also use the E-number system for labeling lobes which, as you know, are representations of the range at which you can get an echo of any particular size in any direction from the antenna. If lobes were drawn to represent all echoes for a particular size target from E-1 (very weak-) to E-5 (very strong) they would appear as

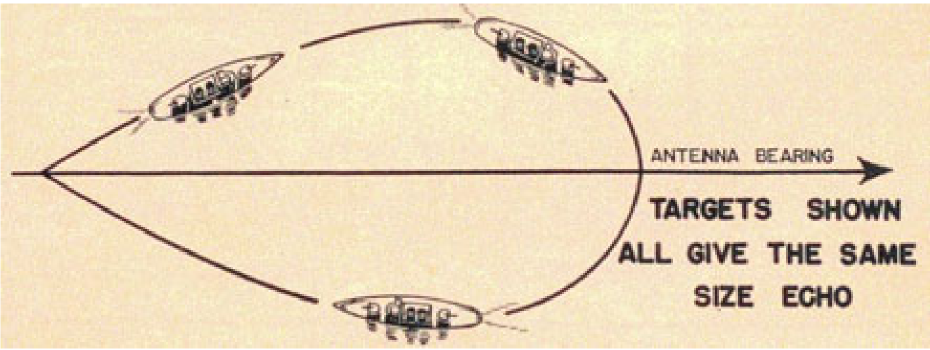


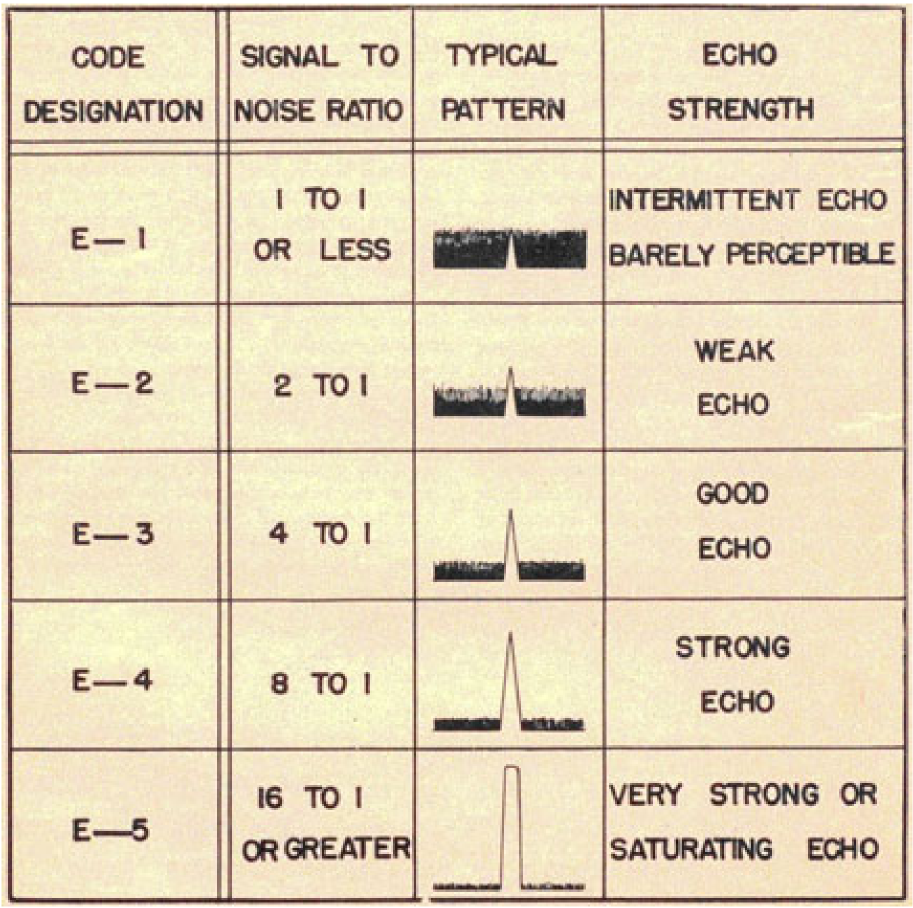
Figure 1-16.

shown in figure 18. This picture is only for one particular size of target. A larger target would have lobes that extend out farther, while a smaller target would not have any lobes as far out as the E-1 lobe in our illustration. What may he an E-1 lobe for a destroyer might be an E-3 lobe for a battleship. Therefore, you could draw a series of the same picture for different types of ships.

The closer the ship is to you, the larger the blip produced, provided that it stays in any one direction from the lobe center. Also, for any range, the size of the returned echo (and thus the blip) is smaller as the direction of the target gets farther and farther from the direction of the lobe. As the target ship steams toward the DL. (direction of the lobe) the opposite will happen. The blip will get bigger and bigger, reaching its greatest size when the antenna is pointing the lobe directly at the ship.

Maximum echo method. Knowing the D.L., you have a way of telling just where the ship is. Simply turning the antenna until you get the *largest* blip or the *brightest* spot, will give you the direction of the target.

Now, let us repeat the procedure in a brief, summarized form. As the target comes steaming in, keeping always at a certain angle with the D.L., the signal



CODE DESIGNATION	SIGNAL TO NOISE RATIO	TYPICAL PATTERN	ECHO STRENGTH
E—1	1 TO 1 OR LESS		INTERMITTENT ECHO BARELY PERCEPTIBLE
E—2	2 TO 1		WEAK ECHO
E—3	4 TO 1		GOOD ECHO
E—4	8 TO 1		STRONG ECHO
E—5	16 TO 1 OR GREATER		VERY STRONG OR SATURATING ECHO

Figure 1-17. "E" unit system for measuring echo.

gets bigger and bigger. (The item of fades which might enter here will he explained later.) The target is changing range without changing its direction from the D.L. This is exactly what is to he expected, because, going hack to the analogy of sound echoes, you know that the nearer you are to the cliff, the louder the echo you will hear. Similarly, the nearer a radar target, the greater the echo received by the radar set.

You cannot affect the range of the target, and hence are unable to do much to increase the it begins to move away from the D.L., the echo begins, to grow weaker. As the target crosses, so that its direction coincides with the D.L., the biggest echo possible from that target and at that particular range is received. This is very convenient, because, as we have said before, you can determine the direction of the target by just turning your antenna around until you get the biggest blip or brightest spot. You know where you have "aimed" the lobe, *so if you set the antenna for the maximum echo, you know the direction of the target*.

height of the blip in this way, while keeping the target on a certain angle with the DL., but if you swing the antenna around a larger echo might come hack to you. lithe target steams along, keeping at the same range, but moving nearer and nearer the D.L., you know that an increasing amount of the energy is hitting it, resulting in a bigger and bigger echo. Conversely, as soon as

This method of setting the antenna (which determines the direction of the lobe), to find the bearing of a target is called the maximum echo method, since you read the direction from which you get the maximum echo. It is the easiest, and consequently the most frequently used method.

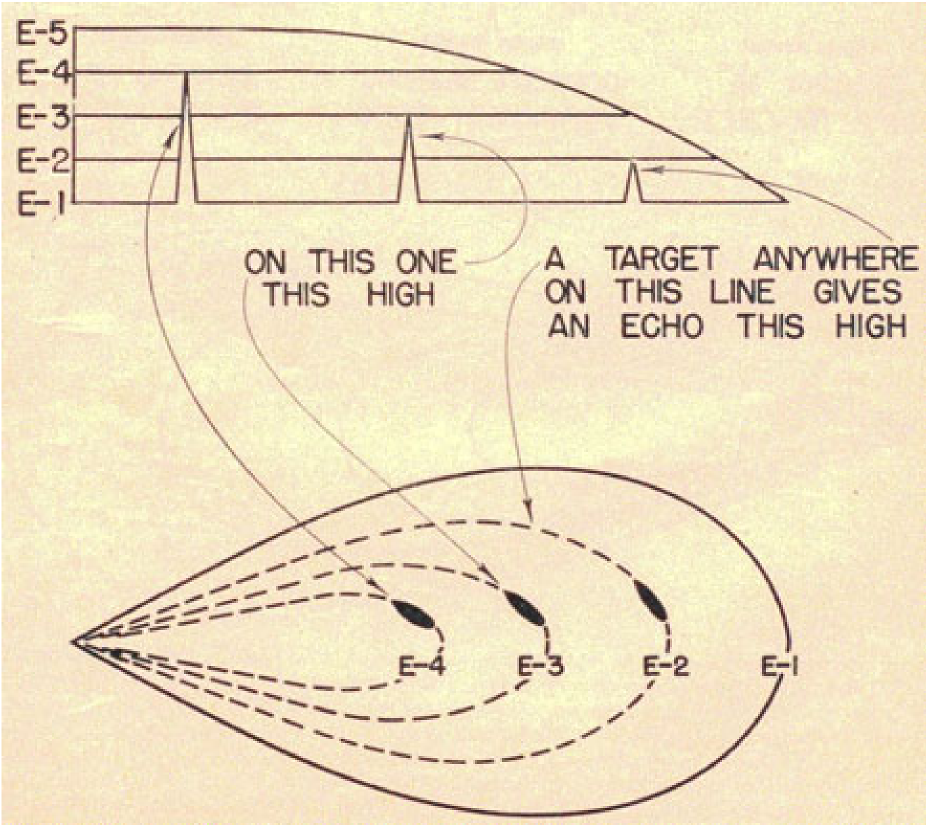


Figure 1-18. Lobe and corresponding echo height.

RADAR OPERATOR'S MANUAL

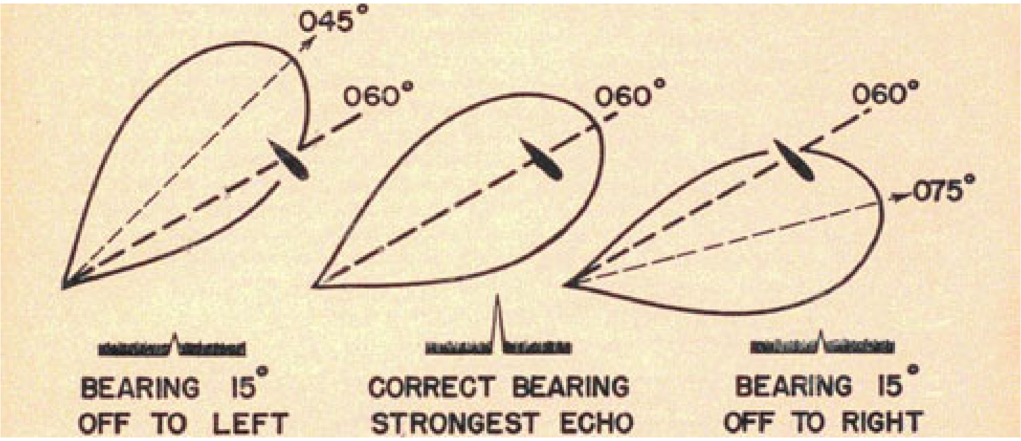


Figure 1-19. Determining correct bearing by echo height.

Accuracy consideration. Let us look at the picture again, noticing especially the nose of the lobe, which is rather flat. That flatness is significant to a radar operator, because it causes greater difficulty in getting *accurate* bearings. Perhaps you are wondering why this should be the case. To begin with, in this case accuracy depends on effecting a big change in what you are looking at, through just a small change in what you are adjusting. If the blip height is what you are looking at (or what you are using to determine when you are on the target), and you are training the lobe in the direction of the target, you can get the bearing of the target accurately if just a small change in setting the antenna gives you a big change in blip height. When you are on the target, you will know it is time to read your bearing indicator. You will then know that the target is on this bearing.

Minimum echo method. Look at the lobe again. Where can you get a bigger change in blip height than near the D.L.? The biggest change you can get will be right at the edge of the lobe. For this sketch, a ship at "A" would be on the barely pick-up, or the minimum echo line of the lobe. It would give you an E-1 echo. If you swing the lobe around toward the direction of the target (the ship), the

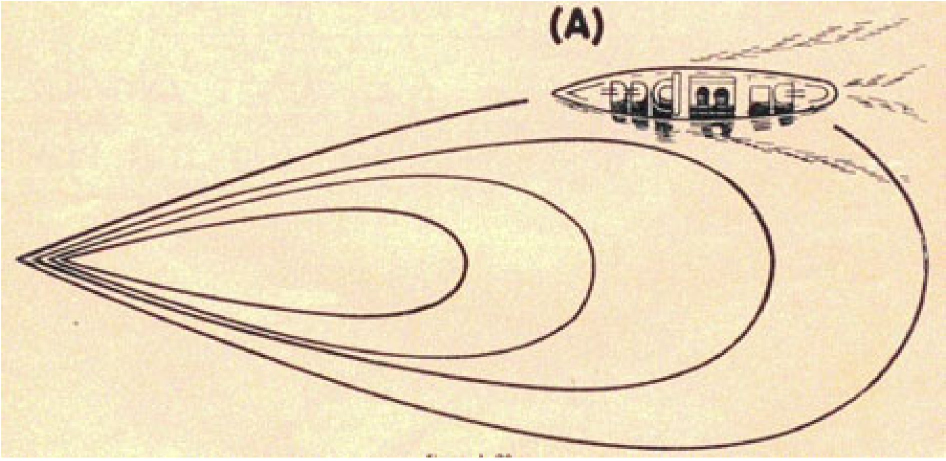


Figure 1-20

GENERAL RADAR PRINCIPLES

echo will get larger, naturally, *but it will increase in size quite rapidly!* In fact, for the sketch shown, the echo strength would change perhaps five times as much in the first degree of lobe trace here near the edge as it would for an equal swing in lobe direction near the center of the lobe. It changes in strength more per degree of lobe train right at the edge than it does anywhere else in the lobe. You can tell when a target is in the edge of the lobe five times as easily (from this sketch) as you can tell when it is right at the center of the lobe. That means that you can set your lobe so that the target is in the edge *much more accurately than you can for the maximum echo*.

However, you find one difficulty: you can read the hearing of the lobe (or the antenna), but not the bearing of the target. Since you want the direction of the *target*, you are interested in the antenna direction only if it can give you this information. In your present situation, it is obvious that you do not know the difference in direction of the antenna and the target. Consequently when the target is in one edge of the lobe, you cannot find the direction of the target simply by knowing the direction of the antenna. You need to know something more.

If you can find the angle between the antenna direction and the direction of the target when it is in the edge, you can either add or subtract this angle from the bearing of the antenna and arrive at the desired answer.

You can set your antenna so that the target is *accurately* in one edge of the lobe and then in the other edge, getting two bearings: one *larger* than the bearing of the target by a certain (unknown) amount, and the other *smaller* than the bearing of the target by the *same amount*. You now know that the bearing of the antenna is *halfway* between these *minimum echo* bearing readings. Average these two bearing readings and you have the *accurate* bearing of the target. This is accurate because you determined the two minimum echo bearings several times as accurately as you could have found the bearing corresponding to the maximum echo.

Lobe switching. So far, you have found two ways of setting your antenna (to direct the lobe), to find the bearing of the target: the maximum echo setting and the minimum echo settings. The minimum echo setting gives you the bigger change in echo size for each degree change in antenna train; hence it is the more precise. However, there is an even more accurate way of setting your antenna, and for two reasons: first, because the side of the lobe is used instead of the blunt end, consequently the size of the echo is extremely sensitive to any small change in antenna train, and second, because an improved method of indication is used, based on the comparison of two pips heights (it is easier to judge when two pips are the same size than to judge when a single pip is at maximum size). This is the procedure called *lobe switching*.

If you have an object that increases in height while another object decreases, the *difference* in their comparative heights will change twice as fast as the height of either one. If two echoes work together in this way to show when you are on the target (one going up and the other down when you get off the target), you can get the antenna set in the target direction just twice as easily as you could by looking at the change in only one echo.

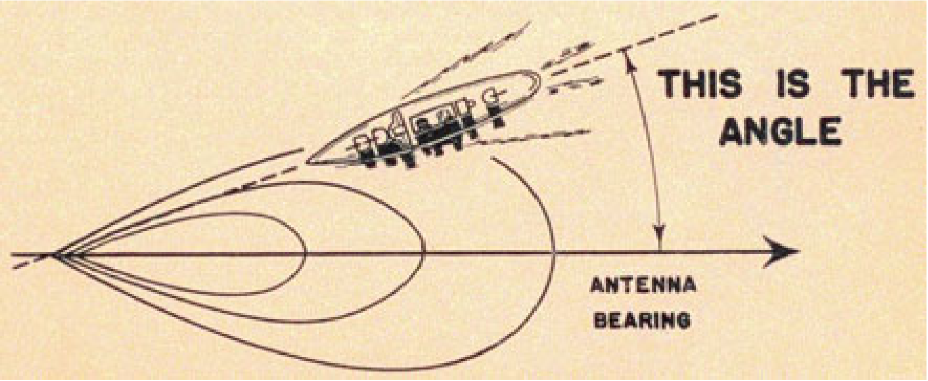


Figure 1-21. Angle between antenna and target direction.

You could create such a situation in this way:

1. Direct the energy out to the port side of the antenna direction and get an echo hack. The size of this echo will depend, of course, on the part of the lobe in which the target appears (see fig. 1-22). With this sketch, the echo would be about an E-2 echo.

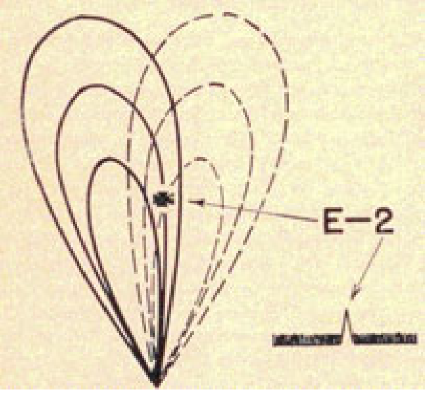


Figure 1-22. Lobe to port.

2. Then direct the energy out to the starboard side of the antenna direction to see how big that echo is. Of course, the echo size depends on its position in this lobe (see fig. 1-23).

the port lobe (in our example), so you get an E-2 echo back from the port lobe and an E-3 echo from the starboard lobe. Now, if you turn the antenna toward the direction of the target, you will be increasing the echo size of the smaller echo, and *decreasing* the size of the larger echo, with the *difference in height changing to ice as much as either echo height*. When you have the target exactly halfway between the two lobes the echoes are matched in height: about three-quarters of an inch high in our example. Each echo has changed perhaps one-quarter of an inch, but the difference changed one-half inch, or twice as much.

Several things must be kept in mind in lobe switching. One point is that you send the energy out on *only one direction at one time*. You send a few pulses out to one side of the antenna direction, and then an equal number of pulses out to the other side of the antenna bearing. You are sending the energy out one way or the other; not both at the same time. Another is that you need to separate the echoes so that you can compare them easily. You can make the blips from the starboard lobe show up a little to one side of the blips from the port side (fig. 1-24), so that the blips will appear side by side. It is vitally important that all the echoes returning from pulses

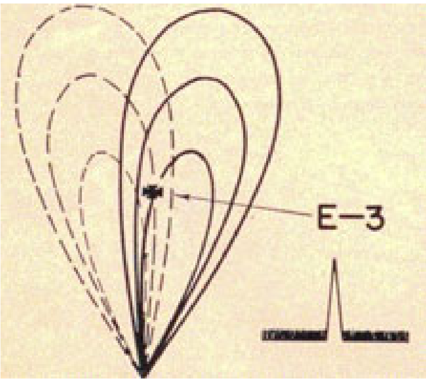


Figure 1-23. Lobe to starboard.

In comparing the size of these echoes you found that they were not the same. Why? Simply because the target is nearer to the center of one lobe than it is to the other. The target is nearer the edge of

sent out to port appear at the same definite position, and that all those returning from starboard pulses appear at another precise position.

Notice that you do not change the direction of the antenna between these pulses: you simply switch the lobes from one side to the other. When you change the antenna hearing, you change the direction of the lobes as well, maintaining their position a certain number of degrees from the antenna bearing. When you get the blips matched you know that the hearing of the antenna is very close to the desired bearing of the target, but you realize that the target is not in the center of either lobe. Since this is true the echo height is smaller than it would be if the target happened to be centered in either lobe:

The lobe switching method is used in some of our fire-control sets, where bearing accuracy is absolutely vital. When bearing accuracy is as important as in the case of fire-control gear, you usually have a separate scope on which to match pip heights. You can find details of the actual method employed in Part 4 of this book, and in the instruction books furnished by the manufacturers of the various sets. On radars such as the SJ or SA, in which cases the precise bearing is not as important as it is in a fire-control set, we use

the conventional range scope ("A" scope) to show the rips to be matched.

You have found that you cannot read the bearing of the target directly, but only the bearing of the antenna. But if you know when your antenna is bearing directly on the target, you can read the bearing of the antenna as the bearing of the target. If the antenna is off the target slightly when you read, you naturally get a bearing that is incorrect. But, if you can tell when you are *off* the target, you can tell when you are *on* the target. The simpler the method for finding when you are *off*, the mote accurately you can read the bearing of the target. The bigger the change produced in whatever you are looking at (the blip height, for instance), with a small change in antenna bearing, the greater the accuracy will be. The *maximum echo* method is the least accurate of the three methods you have studied here because the change in echo strength is small per degree of antenna train. The *minimum echo* method is more accurate than the former, but it takes more time, and so it is not used very often. The *lobe switching* method is the most accurate method in general use. It gives a big change in height difference for a small change in antenna bearing.

Minor lobes. So far, in our discussion of lobes, antennas and bearings, we have assumed that most of the energy goes in one direction and that the amount drops off rapidly as we move away from the direction of the lobe. Unfortunately, this is not always true. Sometimes there will be a considerable amount of energy which has a *definite direction different from the direction of the main lobe.*

When enough energy goes our to form a distinct lobe like this, we say that we have *minor lobes*, or *side lobes* (see fig. 1-25).

What does this mean to you as an operator? The primary thing is that you can pick up a target in a side lobe and report it as being in the main (or major) direction of the antenna assuming that the antenna is trained in the direction of the target. If you have a target in a side lobe, however, and are unaware that it is there, you might think that your antenna is bearing directly on the target, when such is not the case at all, and any bearing reading that you may take will be incorrect. If you have side lobes, the assumption that you can pick up targets only when your antenna bears on them is wrong.

For example, let us suppose that you have side lobes 60 degrees to each side of the main lobe. If your target actually bears 135 degrees, you might read a bearing of 195 degrees or of 075 degrees if you have it in one of the side lobes. That is evident, for your antenna is actually directed 60 degrees to one side or the other of the target.

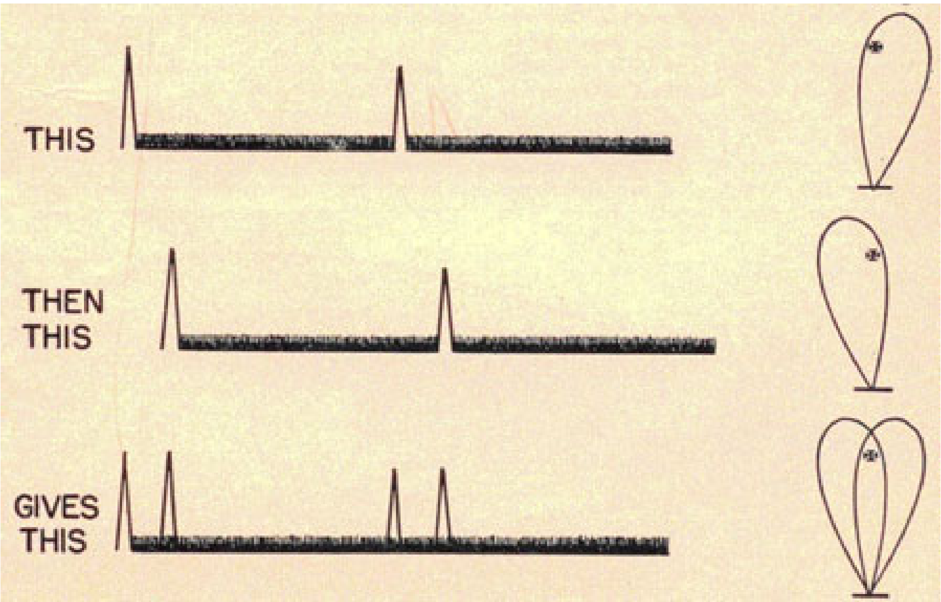


Figure 1-24.

You should remember that it is the bearing of the *main* lobe you read on the bearing indicators, and not the bearing of *side* lobes.

These side lobes occur to some extent with all types of antennas. They are generally most noticeable and troublesome with a curtain array. They occur because the dimensions of our antennas are only a small number of wave lengths. We cannot escape them entirely with our present radar techniques; we must recognize their presence, and be careful to avoid errors resulting from them.

Although these minor lobes may cause errors in establishing bearing, they will not result in incorrect range readings. How to recognize pips from side lobes is discussed in Part 3 under Composition."

The receiver.

echo is built up. A relatively strong echo would require less gain or increase, while a weaker signal would require more gain. Actually, the gain control performs the same task as the volume control on the home set. The reinforced or amplified echo is converted into signal energy, but this energy is not fed to a loud speaker or head phones, since you do nor wish to hear a radar echo. It is your desire to *see* the signal and to derive the information it represents.

The new signal, having been made much stronger and lowered in frequency, is now one that you can use. So far, however, you have nothing to indicate your *receiver output*. For this purpose, you must connect the receiver to a cathode-ray tube, or INDICATOR, which will indicate the return of the echo. The speaker on your home radio set corresponds to the indicator.

The indicator.

To all intents and purposes the radar receiver bears a close resemblance to an ordinary radio receiver. Of course, the two sets differ in frequencies of operation, for the receiver must be tuned to the same spot in the wave band as its associated transmitter, and as earlier emphasized, the bands used by radio and radar are widely separated.

Signal amplification. The receiver used in radar must be very sensitive so as to operate on weak echoes. The power represented in the echo would be of little value if it were not built up in some way. This reinforcing or strengthening action takes place in the receiver, and is called *amplification*. It is the *amplifier* that builds up the weak radio signals into energy that is finally converted into sound issuing from the loud speaker of a radio set.

In the radar receiver the echo is amplified or increased by similar amplifiers. A manually operated gain control enables you to control the amount that the

In radar, extremely small divisions of time are measured. The unit is the microsecond, a millionth of a second. Obviously, no ordinary time-measuring device will serve this purpose. However, it has been found that a device used for many years by television people fits radar's demands well. This is called a cathode-ray tube, or the *scope*. Learning about some construction features of the C.R.T. (cathode-ray tube) will help you to understand how it is used to measure time. *Basic electron theory*. Before discussing the functions of the various parts of the C.R.T. you should know some fundamentals of electron theory with particular reference to how an electron beam is used to measure time.

Scientists tell us that everything is made up of atoms. which are extremely small particles of matter, Each

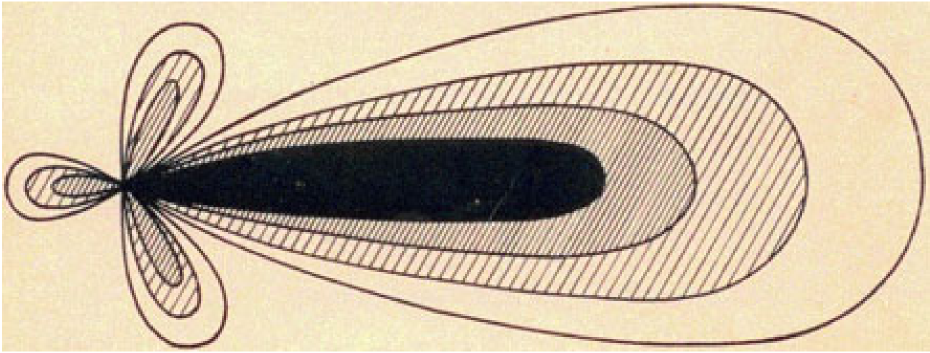


Figure 1-25. Main, minor, and back lobes.

of there atoms has from one to 92 electrons circulating around the center in much the same way as the planets rotate around the sun, except that in the case of atoms the units are billions and billions of times smaller. These electrons continue circulating about the center of the atom until shaken loose by some great impact. When two atoms collide with sufficient force some electrons are shaken loose.

Figure 1-26. Structure of on atom showing electrons in their orbits.

Scientists discovered that by heating material such as metal it is possible to make the atoms within the metal collide with sufficient force and such rapidity that the metal will emit or give off electrons in large numbers. They also discovered that some metals give off more electrons than others, indicating that some materials release their electrons more easily than others.

How well these electrons flow in materials is quite important when electrons may he stored up, resulting in many negative charges. Such matter is said to be at a *negative potential*. Of course, electrons do not do this of their own accord. If free to do so, they will scatter so as to get as far apart as possible (until there is a uniform distribution of the charge. To make them congregate, you must do something to overcome their natural tendency. You can collect them by stroking cat fur, or by rubbing a glass rod with silk, or by connecting up a battery or generator.

If it is possible for them to do so, the electrons will return to atoms which do not have enough electrons. As soon as the electrons are paired off with atoms lacking electrons, everything is back to normal, or a state known as *zero potential*.

Whenever you collect electrons in one place to produce a negative charge, you must get these electrons front somewhere. When electrons are taken from atoms, those atoms do not have enough electrons to be neutral. Since there is a lack of electrons the atoms in question have a *positive* charge.

There are certain facts about negative charges and positive charges that may be stated in the following general law: electrical charges of like kind repel each other, and charges of unlike kind attract each other. In terms of negative charge and positive charge the law is: a negative charge will repel a negative charge; a positive charge will repel a positive charge; a positive charge will attract a negative charge. This is exactly like the principle of magnetism: like poles repel and unlike poles attract each other.

The following is a summary of the main ideas we have discussed on the fundamentals of electron theory.

1. Electrons are small particles of *negative* electricity.

2. Each atom has a certain typical number of electrons. So long as it has this number of electrons, it has no net charge, and thus has zero potential.

3. Conducting materials have some electrons attached very loosely. The atoms can gain or lose electrons easily.

4. Non-conducting materials have the electrons firmly bound to the atoms. Any free electron finds great *resistance* to its movement.

5. When electrons are caused to assemble on, or in, something, that object is said to have a *negative* charge.

6. When electrons are taken away (so that there is an insufficient number to satisfy all the atoms), the object has a *positive* charge.

selecting materials for conductors and insulators. Conductors are materials used for electrical wires because the electrons are held together loosely and can move through the material with relative freedom. Insulators, on the other hand, are materials which hold their electrons very tightly around the center of the atom. Electrons have great difficulty in moving through insulators.

Electrons have a small negative charge. Usually, this negative charge is cancelled by the positive charge of the center part of our atom. This is true, of course, only if the atom has exactly the right number of electrons. If an atom has too many electrons, a negative charge exists, if it has lost some electrons, it is said to have a positive charge.

In conducting materials a large number of extra

7. Electrons will go from a negative charge to a

---

positive charge unless special measures are taken to prevent their doing so. This movement is called a *current*.

8. Like charges repel and unlike charges attract each other.

In order to measure the time it takes for the energy to go out, and echo hack, we must have some instrument to

this grid, being usually negative, repels most of the electrons, but a definite number get through for any particular grid voltage. The less the negative potential (or voltage), the more the electrons that slip by. Figure 1-27 shows the grid (with cathode inside).

The electrons coming out of the grid are moving relatively slowly, and more or less at random. If they are to he used, they must be speeded up (accelerated) greatly so that they will get from the cathode to the screen in a short time. To do this two more parts are placed in the C.R.T.: the first anode and the second anode. Remembering the properties of electrons, you know that a positive voltage attracts the electrons and causes them to rush toward it. This force of attraction depends on the magnitude of the voltage, so to get a strong force, the anodes are put at a high positive voltage. This causes the electrons to move very rapidly toward the anodes, and to shoot through them toward the center of the screen.

indicate its return. Mechanical means, such as an ordinary pencil with gear and lever arrangements Could not operate rapidly enough for this: their weight prevents them from being moved quickly enough to give an indication of the presence of the reflecting object. Since electrons are so extremely light, a beam of electrons may be made to move when the echo returns, and move in just a fraction of a microsecond. This electron beam is used as a convenient pencil to draw the picture of what is happening.

Structure of the electrostatic cathode-ray tube. In a cathode-ray tube the hot metal from which the electrons are boiled is called a *cathode*. This is usually only a small piece of fine wire (something like the filament of an ordinary light bulb), which is heated by an electric current. In order to make the electrons boil off more easily, this wire is usually given a chalky covering of a special material, which is merely a substance from which electrons can easily be boiled. The cathode, then, just furnishes the electrons.

You could control the number of electrons by varying the cathode temperature, but this is a very slow process. Some other method of controlling the number of electrons must be used. A man by the name of De Forest found that a negatively charged piece of metal in the path of these electrons could stop them altogether, while a wire with a smaller negative charge would

The anodes are cylindrical (see fig. 1-28) and are mounted so that the electrons may shoot through the hole in the grid, the hole in the first anode, and the hole in the second anode. Since the electrons

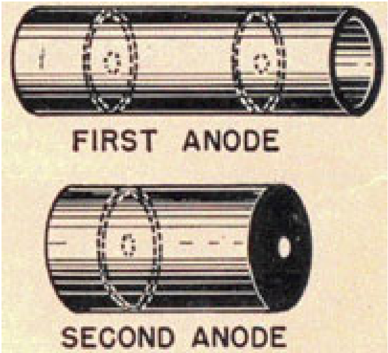


Figure 1-28.

emerge from the second anode at extremely high speed, the complete arrangement of the cathode, grid, first anode, and second anode is sometimes called the *electron gun*.

permit some of them to go by, the number depending on how negative this wire was. He also found that by weaving wire into a grid he could do this more easily than by using just a single wire. We still call this controlling part of the C.R.T. the *grid*, but its actual physical shape is more like a miniature tomato can fitted around (but *not touching* the cathode). There is a small hole in one end to let the electrons out in a stream, or beam. The potential of

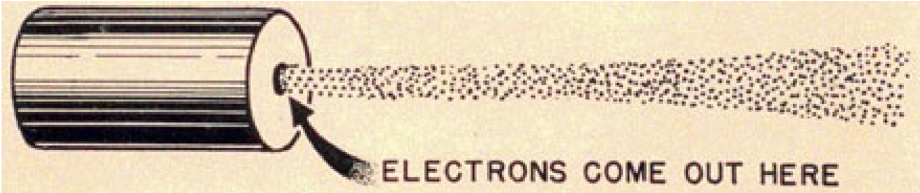


Figure 1-27.

1-30

These electrons continue on and in a very short time strike the glass front of the tube. They are much too small to be seen even with the most powerful microscope, but they can produce effects which are visible. Certain materials will glow and give off light when these electron bullets strike them. If the inside of the tube could be painted with some of this material, you could tell just where they hit by looking for this glow. That is precisely what is done. Since the glass front, painted on the inside with *fluorescent paint* (a substance that glows), is what the picture appears on, we call it the *screen*. Its purpose corresponds exactly to the screen in a motion-picture theatre. Without it, you could not see the pip.

You know that you can attract the electron with a positive charge and repel it with a negative *vertical* deflecting plates because they can cause the beam to move *only* up or down, never horizontally. The vertical position (up or down) depends, of course, on the amount of the charge on these plates, or the *potential difference* between them. A large difference will cause the beam to be either far above or far below the center position, while a smaller voltage difference will cause the beam to appear nearer the center. The beam (or the dot on the screen) may be moved to the right or the left while it is going up or down, but its distance above or below center is always determined by the voltage on V.D.P. Its vertical height, in radar, is independent of the sideways position. For a given voltage on these plates, the dot will appear at a certain height above or below center. For *every voltage on these plates, there is a certain definite vertical position of the dot*, regardless of its horizontal position.

charge, and that the attraction or repulsion is proportional to the charge (or potential). You can move the beam upward by placing a positive charge near the top, or a negative charge near the bottom of the tube, or by both. Likewise you can move the beam to the side by putting positive or negative charges to the side. It is convenient to put these charges in place by using two pairs of metal plates, one pair horizontal and the other pair vertical. These are known as the *deflection plates*, since they deflect the electron beam.

One of the vertical plates is above and the other below the beam. If there is a positive charge on the upper one and a negative charge on the lower, the beam will move upward, since the positive charge attracts the electrons and the negative charge repels them. These charges can be placed on the plates this way by connecting the + terminal of a battery to the upper plate and the - terminal of the same battery to the lower plate. Since these plates *move the beam up or down*, they are called the *vertical deflecting plates* (V.D.P.). Remember that they lie horizontally in the tube, but the direction in which they move the beam is important. They are called the

There is another pair of plates which are exactly like the vertical plates, except that they are turned half-way around so that they are at right angles to the vertical plates. They are able to move the beam to the right or the left, depending on the charges on these plates. Since they control the back-and-forth position of the dot, they are called the *horizontal deflection plates*.

It is obvious that by merely varying the vertical position and the horizontal position of the dot, you can make the dot take any position you want, anywhere on the screen. Consequently, by adjusting the voltages on the two sets of plates properly, you can make the dot appear at any place on the screen. You can make it move in any definite manner by changing the voltage on one or both sets of the plates properly.

Concept of sweep and time base. If the dot moves from left to right at a certain speed, you can use this spot movement as a yardstick with which to measure time. Suppose the distance the dot moves is three inches, and that it covers this distance in exactly 1,200

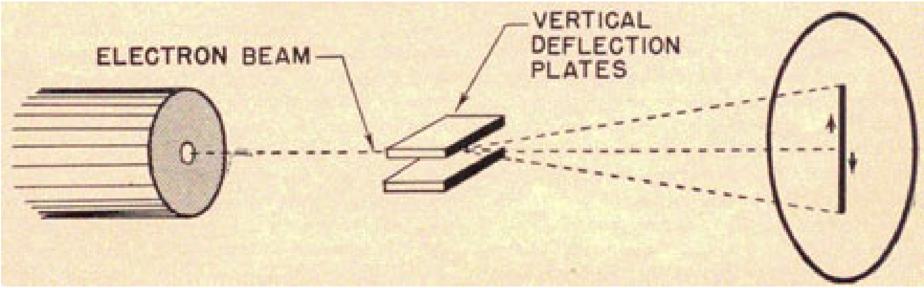


Figure 1-29. Movement of electron beam with change in voltage on vertical deflection plates.

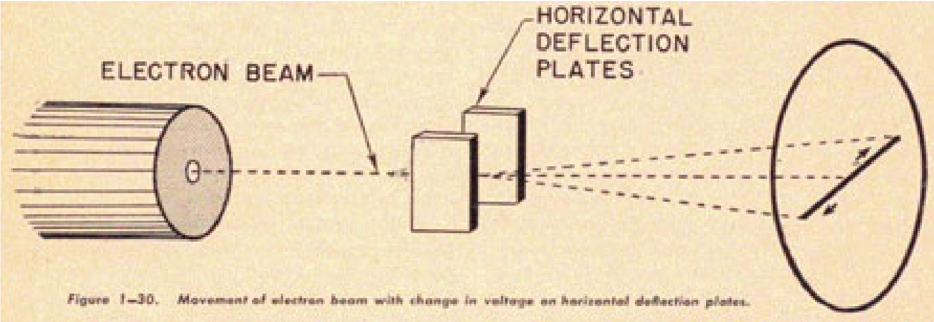


Figure 1-30. Movement of electron beam with change in voltage on horizontal deflection plates.

microseconds. If its speed is constant, it must have moved one inch from the starting point in one-third of the time, or in 400 microseconds. If you drive a car 3 miles in 12 minutes, you could go one mile in one-third of 12 minutes or in 4 minutes. If you set your mileage at zero when you started, and kept the same speed continuously, you could measure the *time* by reading the distance you had traveled. You know that it would take one minute to travel one quarter-mile, and therefore for every quarter-mile you had traveled, you would have been traveling for one minute. If you had gone two and one-quarter miles, you would have traveled nine quarters of a mile, and since it took one minute to travel one-quarter mile, it would he nine minutes from the time you started. Since you move the same distance every minute, the time that has passed since you started is exactly in proportion to the distance you have gone. The spot on the screen of the radar cathode-ray tube moves across the face of the tube in the same way. It starts at one place and moves toward some other place on the tube face. You can control the voltage variations, causing the dot to move in such a manner that it travels from its starting point to the finish point in a certain length of time. It moves across at an *unchanging speed* (approximately) and in a *definite length of time*. This is important the whole ranging procedure used in radar depends on it. Movement of this dot is termed the sweep. RADAR OPERATOR'S MANUAL It takes about 12 microseconds for radar energy to travel to and return from a target a *nautical* mile away. You can, therefore, determine the range (in nautical miles) corresponding to any point on the sweep by dividing the *time* represented by that point by 12 microseconds. Suppose the dot traveled a distance of three inches in 1,200 microseconds. Each inch represents 400 microseconds as before. Any distance along this sweep represents. a certain definite time, and therefore a certain definite range. Since each inch represents a time of 400 microseconds, each inch represents 400 / 12 = 33 1/3 nautical miles (approximately). If an echo returns when the dot

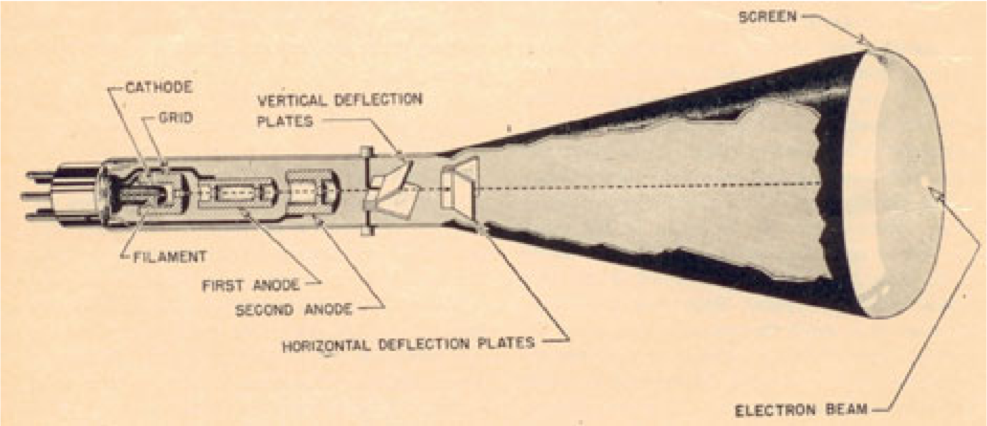


Figure 1-31. Electrostatic cathode-ray tube.

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is one and one-half inches from the start, it would indicate a round-trip time of 600 microseconds, or a range of 50 miles. These actual numbers, of course, can be used only for a sweep that moves three inches in 1,200 microseconds. A sweep of any other speed will have different numbers to tell you what range an inch distance on the scope means.

Since the time and the range to a target always have a fixed relationship, let distance on the scope be marked in range instead of time. Do not forget, though, that you are actually measuring time. In all radar sets, the path of the sweep is marked in units of *range* such as miles or yards (and not time) for convenience in reading. This sweep-line is sometimes called the *time basis*.

So far, you have studied the *electrostatic* cathode-ray tube. You have found that you can deflect the beam by changing the charges (or voltages) on the deflection plates. You have learned that the sweep is produced by varying the voltage on these plates in a very definite way.

In order to understand how this tube works. you need to know something about the principles involved. You may have wondered how an electric motor could pull as strongly as it does. The explanation is as follows. The motor is an arrangement in which large wires carrying heavy currents pass through a strong magnetic field. When these currents flow through the magnetism, a strong force tends to push the current out of the magnetism. *This force is always al right angles to both the magnetism and the direction of the current*. Consequently, the force is in such a direction as to turn the motor. No wire is needed to carry the current because the streaming of these electrons from the cathode to the screen in the cathode-ray tube makes up a current. What happens, then, when you hold a magnet across the neck of the tube? You have placed some magnetism across the beam, and the beam is a current, so the beam tends to move out of the magnetism. It is neither repelled nor attracted by the magnets, but is bent sideways in tending to get out of the magnetism!

The stronger the magnetism, the harder it tends to get out, and consequently the farther from the center of the screen it will appear. If you vary the

Electromagnetic cathode-ray tube. However, getting the sweep on a PPI scope is more difficult because the sweep must change direction but not speed. It is troublesome to get the voltages to cooperate and vary properly. Fortunately, another type of cathode-ray tube is available; using this tube you can get the sweep to move in the desired way with little difficulty. This type is known as the *magnetic* cathode-ray tube.

magnetism between a pair of poles mounted vertically across the neck of the tube, the spot on the tube face will move sideways, farther from the center if you increase the magnetism, and closer to the center if

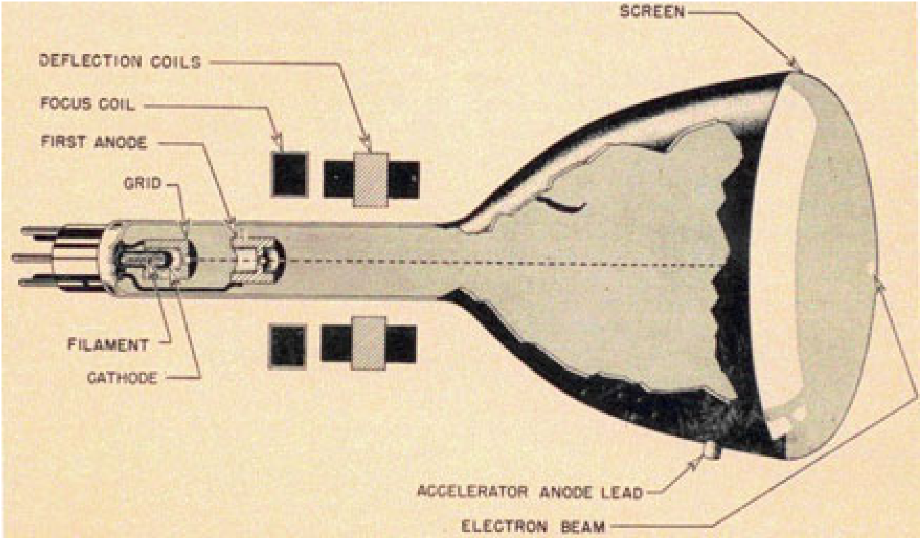

Figure 1-32. Magnetic cathode-ray tube.

you decrease it. Then you can produce a sweep, by varying the magnetism.

If you have ever experimented with electromagnets you know that it is possible to vary the amount of magnetism simply by changing the current through the coils around them. That is just what is done in radar. To get the spot to move and form the sweep, you increase the current through the magnetic coils. The magnet (or held) current determines the position of the spot on the screen. The current in the

can measure the time required for the radio waves to strike an object and be reflected you must have some indication of the precise moment that the echo comes back. You can connect the receiver (which makes echo voltage larger), to either the upper or lower vertical deflecting plates of the C.R.T. When an echo is received, the receiver puts a voltage on one or the other of these deflecting plates, but only for a short time. What would happen if it took six microseconds for the pencil to be moved? The range would always measure about a thousand yards too large. Six microseconds is a very short time in which to move anything mechanical.

By connecting the receiver so that either a negative voltage is applied to the lower vertical plate or a positive voltage to the

control coils above and below the neck, controls the horizontal position of the spot, and that in the coils to the right and the left controls the vertical position.

By varying these currents (and thus the magnetism) you can change the spot position in exactly the same way as was done by changing the charges on the deflection plates. By varying the magnetism properly, you can make the spot draw any desired picture, duplicating any picture that could he drawn on the screen of an electrostatic tube. However, it is easier to produce certain voltage changes than it is to change the currents correspondingly. Likewise, current may sometimes be changed more easily than voltage. Making the spot on the screen move outward first in one direction and then in another (to form the PPI sweep) *without changing the sweep speed* is relatively easy in the magnetic tube. This action is difficult to achieve in an electrostatic tube. You know that the spot must be made to move in this manner, if you are to have a true picture of the PPI (Plan Position Indicator) scope.

The deflection coils are mounted around the neck of the tube within easy reach. Since the sweep is perpendicular to the direction of the magnetism, you can turn the coils around the neck of the tube to change the direction of the sweep. To produce a PPI scope, then, you merely need to rotate the coils as the antenna turns, change their magnetism properly, and intensify the beam when the echo comes back. It would be troublesome trying to use rotating deflection plates on the outside of the neck of the tube,

upper vertical plate of the C.R.T., it is possible to move the electron beam up and then down again in a very short time. It may jump up and back down again within a fraction of a microsecond producing the *pip* or *blip*. What happens vertically does not affect appreciably the horizontal movement, so time can be measured in a horizontal direction regardless of how much the beam jumps up and down tracing pips. It jumps up almost instantly when the echo comes bade, giving an accurate indication of the time that the echo comes back. Therefore, you can measure how long it has been gone with very little error. The electron beam, our "pencil," can be moved with amazing speed.

By making an echo move the electron beam, you get a pip as an indication of the echo's return. This is called the *deflection method* of showing the echo's presence, since the beam is deflected. There is another method by which the echo can be detected, and that is by the beam causing a bright spot to show along the sweep at the instant the echo returns. This method is called the *intensity method*, since the echo causes the screen to be momentarily illuminated by the greater intensity of the beam.

How would you make the sweep brighten up at a particular spot to tell you when the echo returned? Since the grid voltage controls the intensity (or brightness) of any C.R.T., disconnecting the receiver from the vertical plates and reconnecting it to the grid causes the positive output voltage of the receiver (when an echo returns) to intensify the beam and make a bright spot.

To make it easier for a radar operator to see this bright flash, an average voltage is maintained on the grid just sufficiently negative to keep the sweep from showing up except when the echo returns. Then it

otherwise we could use an electrostatic C. R.T. as well as we can use the magnetic C.R.T. Even if the coils are not rotated, it is easy to make the sweep behave properly for PPI purposes by employing simple electrical devices which keep the currents varying correctly.

Echo indication by deflection and by intensity method. You were told that the reason for using an electron beam is to have a "pencil" that can be moved very rapidly. Why is that necessary? Before you

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is bright enough to be easily seen. Thus the target indication is a bright spot or bright smear.

Standard C.R.T. controls. The cathode-ray tube is one of the most important parts of a radar set. It may be thought of as the information center of the equipment.

All cathode-ray tubes have certain characteristics in common. For one thing, all use an electron beam which produces a spot on the screen. There must be some way to control the brilliance and position of this spot. There must also be some adjustment to bring the spot into sharp, clear focus. Controls to make these adjustments are found on the cathode-ray tubes. Let us see just what is the function of each of these controls.

The *intensity* or *brilliance control* enables you to adjust the grid voltage

At the same instant that a pulse is sent out the dot starts at the left-hand side of the tube screen and forms a peak. This peak is traced, because as the transmitter sends out a pulse, the radio receiver detects some of the energy and applies it as a voltage to the *vertical* deflection plates in such a way that the dot is pulled upward following the shape of the transmitted pulse. As the radio wave continues toward the target, the dot also moves at a constant rate of speed from left to right, leaving a trace behind it. In other words, we can look at the dot and see what the wave is doing.

Now, as the radio wave strikes the target and returns as an echo, the dot still keeps moving. Then at the same instant that the echo reaches our position, another peak is formed by the dot because the radio receiver detects and amplifies the echo energy and again applies a voltage to the vertical deflecting plates. This peak, caused by the echo, is called a *pip*.

After the pip is traced, the dot still continues its travel to the right on the scope until it completes the time base. Notice that before the next pulse is sent out there is a definite lapse of time after the echo is received. The most distant echo should have time to return before the next pulse goes out. This interval allows us to identify each echo and the exact pulse that caused it.

(with respect to the cathode) and thus control the number of electrons striking the screen. It should always be adjusted for minimum intensity allowable.

The *horizontal centering control* of an electrostatic (I.R.T. controls the direct current voltage on the horizontal deflection plates, permitting you to move the complete trace to the right or left.

The vertical centering control of an electrostatic C.R.T. permits adjustment of the voltage on the vertical deflection plates so that the complete picture may be moved up and down.

On a PP! scope, horizontal and vertical positioning is effected by actually moving the focus coil up and down or sideways. These are semi-permanent adjustments made by the technician.

The *centering control* of a PPI scope permits making the sweep start in the center of the screen. This is done by controlling the direct current flowing in the deflection coils of the magnetic C.R.T.

A *focus control* is used on every cathode-ray tube to permit bringing the dot to a sharp focus. This is done by varying the voltage between the first and second anodes of an electrostatic C.R.T., and by varying the current in the focussing coil of a magnetic C.R.T.

The *astigmatism control* is a secondary focus control. By varying the direct current voltage on both vertical (or both horizontal) deflection plates, any part of the sweep may be brought into sharper

For the purpose of explanation, we have slowed down the action of a single pulse, its returning echo, and corresponding pulse trace and pip on the scope. The actual speed and flow of radio energy is that of

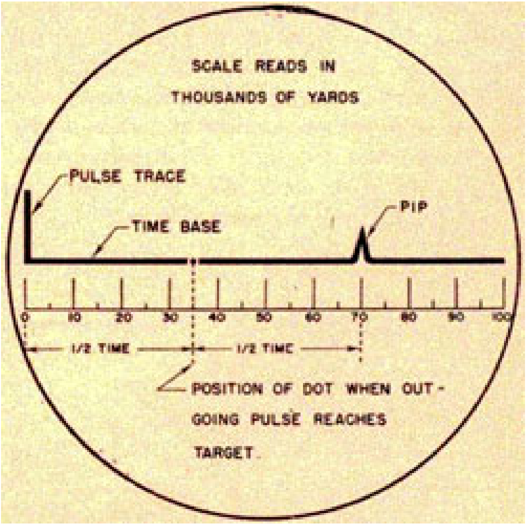

Figure 1-33.

focus than is possible by using the regular focus control.

Development of trace by the electron beam. In order to see more clearly the action of the C.R.T., let us follow a pulse from the transmitter and see what happens on the scope screen (see fig. 1-33).

the speed of light, so that the time base with the pulse trace and echo pip on the scope will appear to he stationary or fixed. Keep in mind that there is a definite relation between the rapid dot travel on the scope and the radio wave travel between our position and the target.

The distance between the pulse trace and the pip on the time base is actually the "yardstick" for measuring the distance between own ship and the target. The C. R.T. translates the smallest fraction of time into exact physical distance of yards or miles. It can be seen that the scale most be calibrated so that its indications actually divide by two the total distance traveled by the radio wave.

Continuous and discontinuous sweeps. You know that the electron beam travels across the screen in a definite manner and in a definite time. You also realize that there is one sweep for every pulse sent out by the transmitter; consequently, the time between pulses puts a limit on the time length of the sweep Sweeps that use up all of this time differ slightly from those which do not, so there are different microseconds. When it reaches the end, it has to wait 1,080 microseconds before it can start over. You would refer to this as a discontinuous sweep because of the rest period, during which the scope is blanked out (turned off).

If you decided to look for targets as far as 25 miles, you would have to *slow* the dot down until it took 25 X 12, or 300 microseconds to cross the screen. Its rest period now will be 900 microseconds (with 833 pulses per second). This would he called a *nominal range* of 25 miles, because that is the biggest range that can he read directly on the scope with this sweep speed.

You can increase nominal range to 50 miles by further slowing the dot until it takes 600 microseconds to complete the trace. Then an echo from a 50-mile target would get back just in time to show up on the scope. If an echo returned from a target beyond 50 miles, it would arrive during the 600-microsecond rest period, the time when the scope is blanked out.

What would happen if the dot were slowed until it took the full 1,200 microseconds to go across? For one thing, the nominal range would be 100 miles. Furthermore, there would be no (appreciable) rest period. Up to this point slowing the dot increased the nominal range. It is not possible to continue to increase the nominal range by slowing the dot still more since you are allowing only 1,200 microseconds between starts of sweeps. Hence, any further reduction in speed using this pulse repetition rate will only shorten the length of the

names for them.

A continuous sweep is a sweep in which the dot needs the complete time (practically) between pulses to get across the scope. It travels continuously, because it jumps back and starts over immediately after it completes one trip. A discontinuous sweep is one in which the dot completes its crosswise trip considerably ahead of the time it is to start across again, so it "rests" awhile. It shows no echoes during the rest period, as it does not sweep across continuously.

Suppose that you have a radar set pulsing 833 times every second. This means that the time between starts of sweeps is 1/833 of a second, or about 1,200 microseconds. If you are interested only in targets within about 10 miles, you need consider only echoes coming back within about 10 X 12, or 120 microseconds. Since the dot can be set to travel at any speed you choose, you can make it go across the screen in 120 trace. Further, slowing the dot cannot increase the pulse interval -the maximum time of travel. It will only shorten the distance the dot travels, which usually is not desirable.

You have found that so long as you have a discontinuous sweep, the nominal range can be changed by changing the speed of the sweep. The only way you can change the nominal range of a continuous sweep is by changing the pulse repetition rate. The nominal range is determined by the time the dot takes to cross the screen, and that, for a continuous sweep,

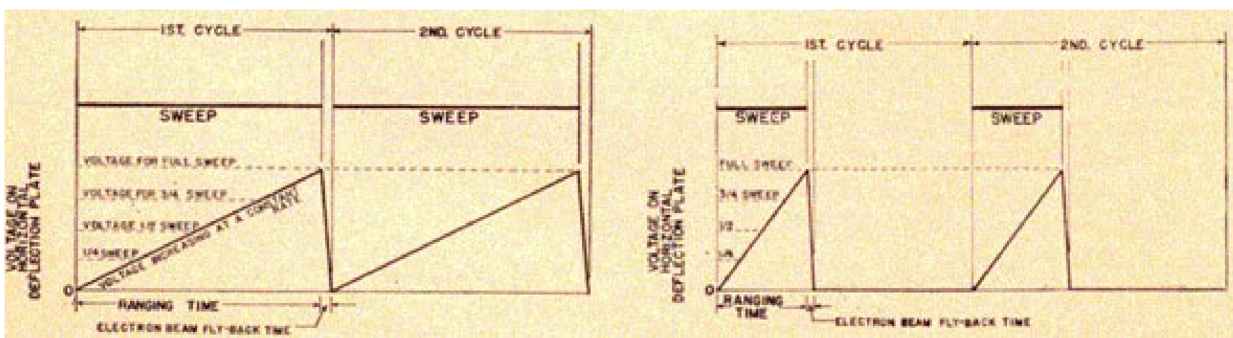

Figure 1-34. Continuous sweep.-Discontinuous sweep.

GENERAL RADAR PRINCIPLES

is the same as the time between starts of pulses. Increasing the *number* of pulses decreases the *time* between them, and so reduces the nominal range.

The following is the equation for calculating the nominal range of a continuous sweep:

N.R. = 1,000,000/12 X P.R.R. (approx.). N.R. is the nominal range in nautical miles. P.R.R. is the number of pulses the transmitter sends out every second.

There are advantages associated with both the continuous and the discontinuous sweep. As long as a discontinuous sweep is used you can switch scales *simply by turning a knob*. Since the only thing that needs to be done to change the nominal range of a discontinuous sweep is to change the sweep speed, you can put in a rather simple control to make a quick, easy change possible. Changing the sweep speed is easy. The pulsing rate, on the other hand, cannot, in some cases, be changed much, so sets with continuous sweeps usually have only one scale.

The sweep speed of a continuous sweep can be changed on some radars so that the sweep starts slowly, then speeds up, and finally slows down again without altering the time of the start and ending of each sweep. The total range indicated by the sweep is unchanged since the total time of the sweep remains the same. However, both ends of the sweep register a greater proportion of the total range, for they represent a greater part of the total time due to the reduced speed of the spot. The center portion that has been speeded up now represents less of the total range since its time is reduced, but it represents an increased part of the physical length of the sweep. This results in expanding the picture of any objects appearing in this center section of the sweep because it now echoes. Calibration simply makes the set indicate proper range, bearing, and position angle.

Range calibration is necessary in the ease of every radar set. Every operator *must check his range calibration* every time he takes over a watch. There are two things that must be done to make the scope read correct range, internal calibration and external calibration.

Internal calibration. The purpose of internal calibration is to make the divisions on the scales the correct length. It is the same problem as making the inch-marks on a ruler exactly one inch apart. You could not measure distances accurately with a ruler if the regular inch-marks were really three-quarters of an inch apart, for you would be reading each distance too long. An actual three inches would only occupy four of these three-quarter inch spaces, with the result that you would think the object had a length of four inches.

Radar internal calibration deals with the same sort of proposition. If the spot moves across the screen in, say, 900 microseconds when the scale is marked off for a 50-mile nominal range, you would read a range of 50 miles for a target that actually was at 75 miles.

Internal calibration is the process of making the time of the sweep match the scale: making the dot move from the start to the end in the *correct amount of time*. For a continuous sweep, this time is the time interval between pulses, so you must get the correct *pulse repetition rate for a continuous sweep*. If you have a discontinuous sweep, this time depends only on the *speed of the sweep*. Consequently, internal calibration requires determining either the correct pulse repetition rate or correct sweep speed.

External calibration. External calibration is the process of making the zero setting correct, to avoid any constant range error. Unless you make this adjustment, you may read a range too large or too

covers a greater part of the sweep length. This has certain technical advantages which makes accurate ranging relatively easy.

Calibration of continuous and discontinuous sweeps is discussed in the following section on "Calibration." There you will find that the calibration of a continuous sweep is different from calibration of a discontinuous sweep.

Calibration.

Radar sets, like every other precision instrument, must be *calibrated* before they can give correct information. Calibration is the process of making the radar read the *correct range*, *bearing*, and *position angle*. It is a common error to think that the term calibration includes tuning the receiver, adjusting the dial lights, throwing switches, and everything else necessary to get small by a definite amount.

Imagine a yardstick with the first five inches cut off (so that the five-inch mark is right at the start). Unless you made proper allowances you would read a length five inches too great for anything measured with this yard stick. The 25-inch mark would be at the edge of a 20-inch box, and the length of the box would appear to be 25 inches. If you moved the yardstick over five inches, placing the five-inch mark five inches from the left edge, you could read the correct length of the box. Its edge would line up with the 20-inch mark.

You can do exactly the same thing with your radar set. You cannot actually read a zero range (because of the transmitter pulses), but you can detect nearby

targets on your radar and make their pips appear at the correct places on the scope. Double range (or multiple range) echoes are useful in doing this (see the section on Multiple Range Echoes in Part 3).

All radars should have the zero setting checked s often as possible, either by comparison with a set

If you subtract the range you actually read for the double range echo from double the range read for the target, you will get the correction you should make in the zero setting, and reduce the zero reading by this amount. In the example, double the range read for the target was 7,000 yards. The range reading for the double range echo was 6,500 yards. Subtracting 6,500 yards from 7,000 yards leaves 500 yards, the number of yards *too many* your set is indicating.

If you move the zero setting back 500 yards, the normal echo will appear at 3,000 yards and the double range echo at 6,000 yards. Twice 3,000 is 6,000, so you know your *zero set* is correct.

This method is useful for calibrating fire-control radars. It can be used to a lesser degree with search type radars, if there is another ship parallel to yours

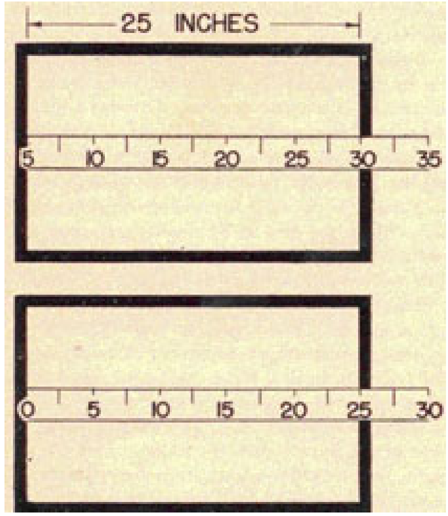

Figure 1-35. Measuring a box with two different scales.

known to be accurate or by the double range echo method, which is the most accurate and convenient method to use, especially when at sea.

Double range echoes occur at close ranges and result from the reflected energy striking your ship, returning to the target, and being reflected a second time. Therefore, you should see a blip created by the reflected energy returning on the first trip; then a second blip, which will be smaller, should appear at exactly twice the actual range if the zero setting is correct. With this information, the exact range to the target can be determined, for it is the difference between the second trip echo and the first trip echo (6,500-3,500). Next, you will learn how to find the zero setting so that the actual range will be correct.

at a short range.

Range calibration consists of two steps. If you have a discontinuous sweep, you must get the *sweep speed* (internal calibration) and *zero setting* (external calibration) correct. If you have a continuous sweep, you must get the pulse repetition rate (internal calibration) and zero setting (external calibration) correct.

Bearing and position angle calibration should be checked against the optical methods. Some of the search equipment in use does not require frequent calibration for bearing or position angle. This is not true of the fire-control radar, where extremely accurate hearing or position-angle readings are needed, and such a radar should be checked as often as possible.

Types of scopes.

Through the use of radar it is possible to get information when all other methods fail, but this information is absolutely useless unless it can be put in understandable form. For certain uses, this information is more understandable when presented in a particular way, while for another job, some other manner of presenting the data may be more desirable. There are several ways in which the same information

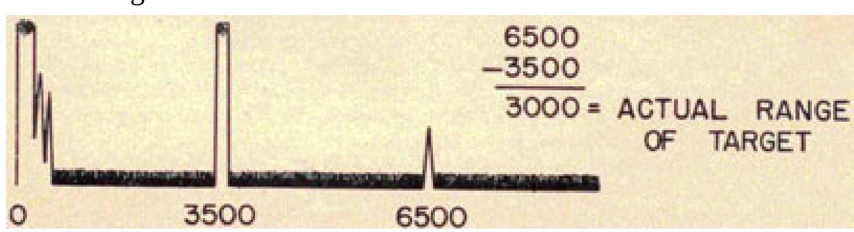

Figure 1-36. Zero set is off 500 yards.

GENERAL RADAR PRINCIPLES

can be shown, and the particular method used will depend on the specific job.

The information you are interested in primarily is detecting the presence and finding the location (range and bearing) of objects. Just how does the radar set show this? If there were a few million vacuum tubes, coils, condensers, and resistors in the set, you could make the beam perform somewhat as shown in figure 1-37.

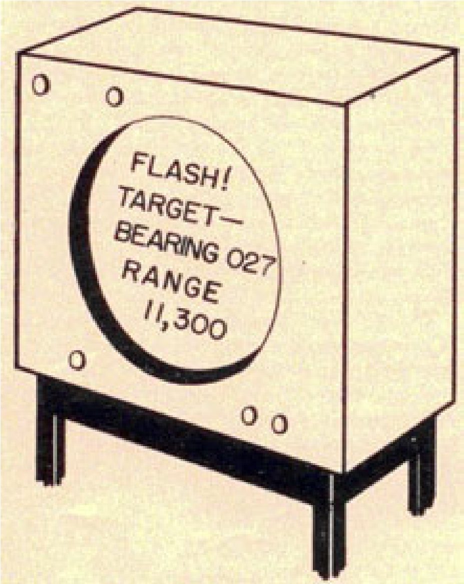

Figure 1-37.

Unfortunately there is no room for the many complicated circuits required for this outfit, so instead, simpler, easier methods may be used-many of them. Six of these methods and their uses will he discussed here: the "A" scope, "B" scope, "PPI" scope, "H" scope, "R" scope, and "J" scope.

The "A" scope. The fundamental type is known as the "A" scope. It is the type most frequently referred to during previous explanations. You time base, it gives the dot a kick upward, forming a pip or blip which indicates a target.

We may determine the range, then, by measuring the time from the start of the sweep to the spot at which the pip appears, translating the time into range. Since the speed of radio waves does not change, the indicator is usually marked off directly in yards or miles. Hence, the "A" scope indicates range horizontally and presence vertically. It tells nothing about the bearing of the target.

The "A" scope has advantages which often outweigh its failure to tell the bearing of a target. One important characteristic is its ability to tell you what you are "looking" at-just what the blip indicates (see section on Composition in Part 3).

The "A" scope is useful when trying to detect the presence of objects at long ranges. *Fairly weak echoes may sometimes be detected on the "A" scope before they can be seen on another type of scope (especially when the pulsing frequency is high).*

Ranges can readily be determined with accuracy on an "A" scope. Some scopes provide a range step in the sweep, and control its position electrically to facilitate the task of range measurement, The step appears because a voltage is suddenly applied to a vertical deflection plate, which causes the remainder of the sweep to he shoved down.

Dials or scales which will read the range of our step directly and accurately are provided. When you move the step under the blip of the target, the range of the target appears on these dials. This greatly simplifies the task of accurately determining range (this step is usually not so sharp as that shown in the

remember that the spot moves from the left to the right side of the screen at some approximately constant speed, enabling you to measure time from the start to any point along the time base. The spot jumps up whenever a reflected echo returns simply because the receiver output is connected to one of the vertical deflection plates. The echo comes out of the receiver and regardless of where the dot happens to be on the

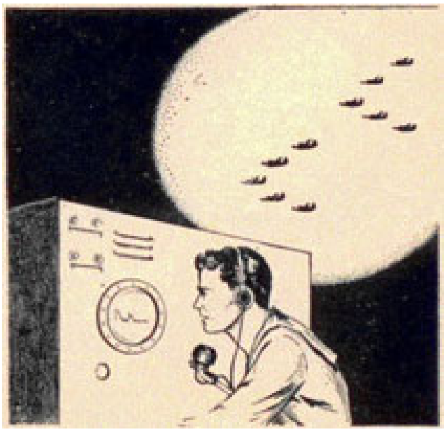

Figure 1-38. Two groups.

sketch, and it may be altogether different in shape, but the basic idea is the same).

Before leaving the "A" scope, let us review briefly the facts known about it. First of all, when an object is reflecting the transmitted energy the spot jumps up, tracing a triangular-shaped pip (this might well be the reason it is called an "A" scope since the blip resembles the letter "A" without the cross bar). The presence of the target, then, is shown vertically. The farther an object is from you, the more time the energy will require to go out and return, so the spot tracing the time base will get farther across the screen before the echo returns. Range can be found by seeing how far the blip appears from the start of the sweep. Range may he determined directly with ease and accuracy; presence may he detected on the "A" scope although the echo is weak. Variations in appearance of the blip can tell you much about what is on the reflecting end of the radar beam.

The "A" scope itself tells nothing at all about the bearing of the target. However, you can tell when the antenna is pointed directly at the object, thus the antenna bearing will be the same as that of the which rotates in synchronism with the antenna points to the proper reading on the dials. This type bearing indicator is found on many radar sets in use at the present time.

The "J" scope. A new model radar recently introduced to the Fleet has a *circular sweep*. The dot, instead of traveling from one side of the screen to the other as on the "A" scope, goes around and around (somewhat like the sweep on some sound ranging gear). When an echo returns, the dot suddenly jumps outward to form a blip. This blip is straight out ("radially," we say), and time is measured by its distance from the start of the sweep around the screen. On this scope, range is shown *circumferentially* (around the circle) and presence radially.

For any particular size of cathode-ray tube, the time base is about three times as long as it would be on a corresponding "A" scope. So, by wrapping the "A" scope around in this way, it has been possible to increase the range accuracy about three times. The "J" *scope presentation* is the name given to this novel indication.

target. Thus by reading the bearing of the antenna you find the bearing of the target relatively easily, but there must be a *bearing indicator* to show the antenna bearing. This is usually made up of two circles marked off in degrees; one reads the relative hearing, the other the true hearing. A pointer (called the *bug*)

The "R" scope. A modification of the "A" scope, of great value in determining the composition of targets (see section on Composition), is now found on some sets. It is called the "R" scope, and is a magnified (expanded) portion of the "A" scope with a control which enables you to choose the part to be magnified.

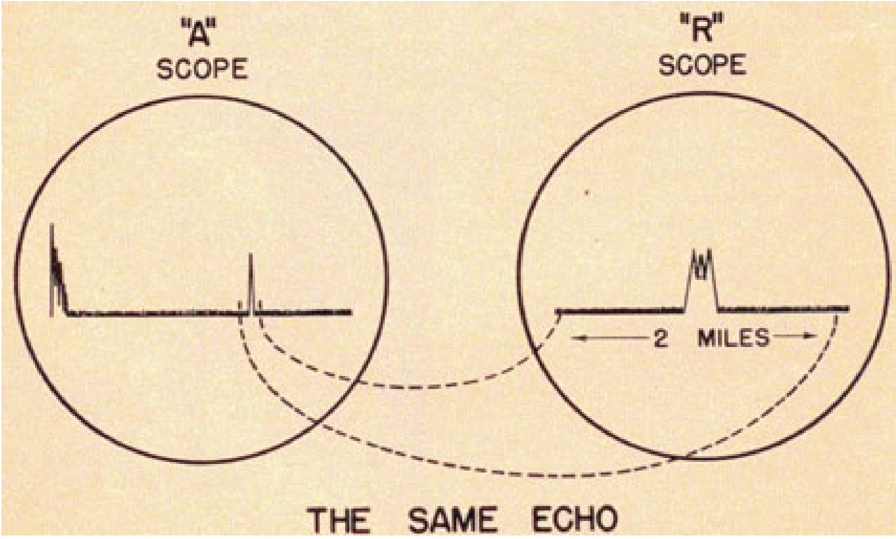

Figure 1-39. Magnifying a portion of the "A" scope with an expanded sweep.

To magnify the pip, you cause the spot to move across the scope in a short time. It may cover the five inches (approximately) of the time base in just 25 or 30 microseconds. This, of course, will make the pip appear very wide. For instance, a pip five microseconds wide might cover a whole inch on the time base. Two targets separated by only a half mile will appear almost an inch apart. Consequently, the operator is not likely to read the indication as being a pip from a single target.

By increasing the width of the pip in this way, it is possible for the operator to recognize definite features thereof. You can count the separate peaks running up or down the sides of the pip, and separate targets close together which might

direction representing the antenna beating. Since the antenna can pick up an echo from a target only while it is pointing at that target, and since the rotating antenna points in any target's direction for but a short time, you can expect the bright spot to appear for only a moment. As the radar beam swings away from a target, you fail to receive any echo from it, and consequently, the beam does not make a bright spot any longer. (You recall that the beam can intensify only contacts on one bearing at a time.) This means that in order to continue to see that particular target, the screen must continue to glow after the sweep leaves it. In making the cathode-ray tube, the screen is painted with a chemical coating that glows longer than the "A" scope screen coating, and a tube with a longer persistence screen results.

otherwise be mistaken for a single target. The job of estimating size, number, etc., is greatly simplified by use of the "R" scope.

The "A" scope, the "J" scope, and the "R" scope all operate by deflecting the electron beam when an echo returns. Hence we say that they *indicate presence by deflection*. However, it would be possible to have a bright spot appear when the echo returns instead of deflecting the spot. This brightening of the spot is called the *intensity method* of showing presence, and it is used in both the PPI scope and "B" scope presentations,

The PPI scope. The PPI scope gives us a top view of the vicinity, with our own position in the center. Draftsmen call a top view a *plan* view; since the scope indicates a top (or plan) view of the position of everything around you it is called a *plan position indicator*, or as abbreviated, a PPI scope.

The pictures of the surroundings appear by this simple process: the sweep begins in the center and goes outward (at its constant speed), toward the edge *in the direction the antenna is pointing*, and a *bright spot appears at a distance proportional to the range of the target*. Those who have done any plotting will recognize this method: placing a mark in the correct *direction* and at the correct range on a polar chart. That is all that is needed to draw a true map of everything in the vicinity. This scope shows everything that can reflect the radar energy, and shows it in the proper place on the PPI map. You will see islands, your own ships and planes, as well as the enemy's craft, and anything else that happens to reflect the energy; all objects appearing in their *actual positions*. You can readily see how helpful this PPI scope is in task-force operations, in convoy duty, in working navigation problems, or in any one of various technical uses.

A screen is termed persistent because it *persists* in glowing after the sweep has left it and has moved on to another spot. Tubes which employ the intensity method are used in PPI and "B" scopes.

The "B" scope. The "B" scope resembles both the "A" scope and the PPI scope, but has some characteristics of its own. If you turn an "A" scope on its side, the range will be indicated upward, or vertically, and the blip horizontally. With the receiver disconnected from the horizontal deflection plates, it will not be possible to get a blip sideways. By connecting the receiver to the grid instead, a bright spot will result which will indicate a target just as a blip does. Seeing a bright spot is the indication of the presence of an object, and the spot's position tells you the range of the object causing it.

The horizontal deflection plates have been disconnected, and are not in use. What use could be made of them? Range is determined vertically and presence by intensity, so the one item of major information lacking is the bearing. The horizontal plates, then, can be used to determine the bearing of the object in the following manner.

If the whole time base could be moved, bright spot and all, to one side for a distance proportional to the movement of the antenna, it would provide a means of indicating the bearing of anything giving an echo, because the scope would show how far the sweep was from its usual position. For example, suppose the time base moved one inch to the right when the antenna was trained five degrees to starboard. If a bright spot showed on the time base one and one-half inches to the right of the center, the antenna must have been pointing seven degrees and thirty minutes to starboard when the echo was received. Consequently, the target was at an angle of seven degrees

Remember that the sweep moves outward in a

and thirty minutes to starboard. In some sets (such as the Mk. 8), the scope tells the angle of a target to the right or the left of the line along which the director points.

Usually, the "B" scope is used with sets which do not show targets for the full 360 degrees about the ship. Most of them show targets in only a limited area, such as a sector from 285 degrees forward, to 075 degrees relative, Other sets search a sector only 30 degrees wide, 15 degrees to each side. How you set the "blinders" depends on what you are looking for.

What, then, does the "B" scope show? Since it is similar to an "A" scope that does not stay right side up, it *shows range vertically*. The electron beam brightens up the screen when an echo returns, and consequently shows the *presence by intensity*. Finally, the horizontal plates are connected so that it shows the *bearing horizontally*. It gives the same information as the PPI scope, but in a different manner.

Since the sweep always starts at the bottom and goes upward-always in the same direction-you can measure range accurately. A movable pointer is sometimes used, or moving the sweep past a stationary pointer can serve to measure the range with reasonable accuracy. There is no problem here of measuring different directions, as in the case of the PPI scope. When no critical range accuracy is required, horizontal lines are placed on the screen to be used in estimating ranges, and vertical lines are used in estimating the bearing of a target.

The "H" scope. An "H" scope is a modified "B"

Bearing:	No bearing indication
Advantage:	Great ease in determining composition.

"H" SCOPE

Range:	Vertically
Presence:	Double dot
Bearing:	Indication horizontally
Advantages:	Provides bearing and range plus data for altitude determination,

"J" SCOPE

Range:	Around circumference
Presence:	Radially
Bearing:	None
Advantage:	Increased range accuracy.

PPI SCOPE

Range:	Distance out from center of scope (radially)
Presence:	Intensity
Bearing:	Direction of sweep
Advantages:	Complete picture in a few seconds. Shows all objects in true relative positions.

"B" SCOPE

Range:	Vertically
Presence:	Intensity
Bearing:	Horizontally

scope. Azimuth is given horizontally, and range vertically. The signal appears as two bright spots, displaced laterally with reference to each other. The slope of the line that can be imagined as joining the dots gives an indication of target elevation. The "H" scope is often designated by the term *double dot scope*.

Summary. The following summary gives in brief form the function of each of the scopes, and provides a means of comparing features of the various types.

"A" SCOPE

Range:	Horizontally
Presence:	Vertically
Bearing:	None indicated
Advantages:	Ease in detection, ranging, and determination of target composition.

"R" SCOPE

Range:	Horizontally
Presence:	Vertically
Advantages:	Good bearings at any range; good bearing resolution or target separation at short ranges as contrasted with PPI; shows all targets at the same time. Similarity to cross-hairs makes it especially good for gunnery.

The modulation generator.

So far, you have discovered that the radar set has these parts: the *transmitter*, the *antenna*, the *receiver*, and the *indicator*. There is more to the set than this, however. You know that an operator is needed to key the communication code set, for someone must turn it on and off to form the dots and dashes. Similarly, radar energy must he sent out in pulses (or extremely short dots) if you are to get the accurate range of an object. These pulses must all he of the same length, and must he spaced evenly over a period of time. This means sending a pulse only four or five microseconds long, and 1,640 of these must he transmitted in one second. Some radar sets require a device to do just that, so an electrical means of

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GENERAL RADAR PRINCIPLES

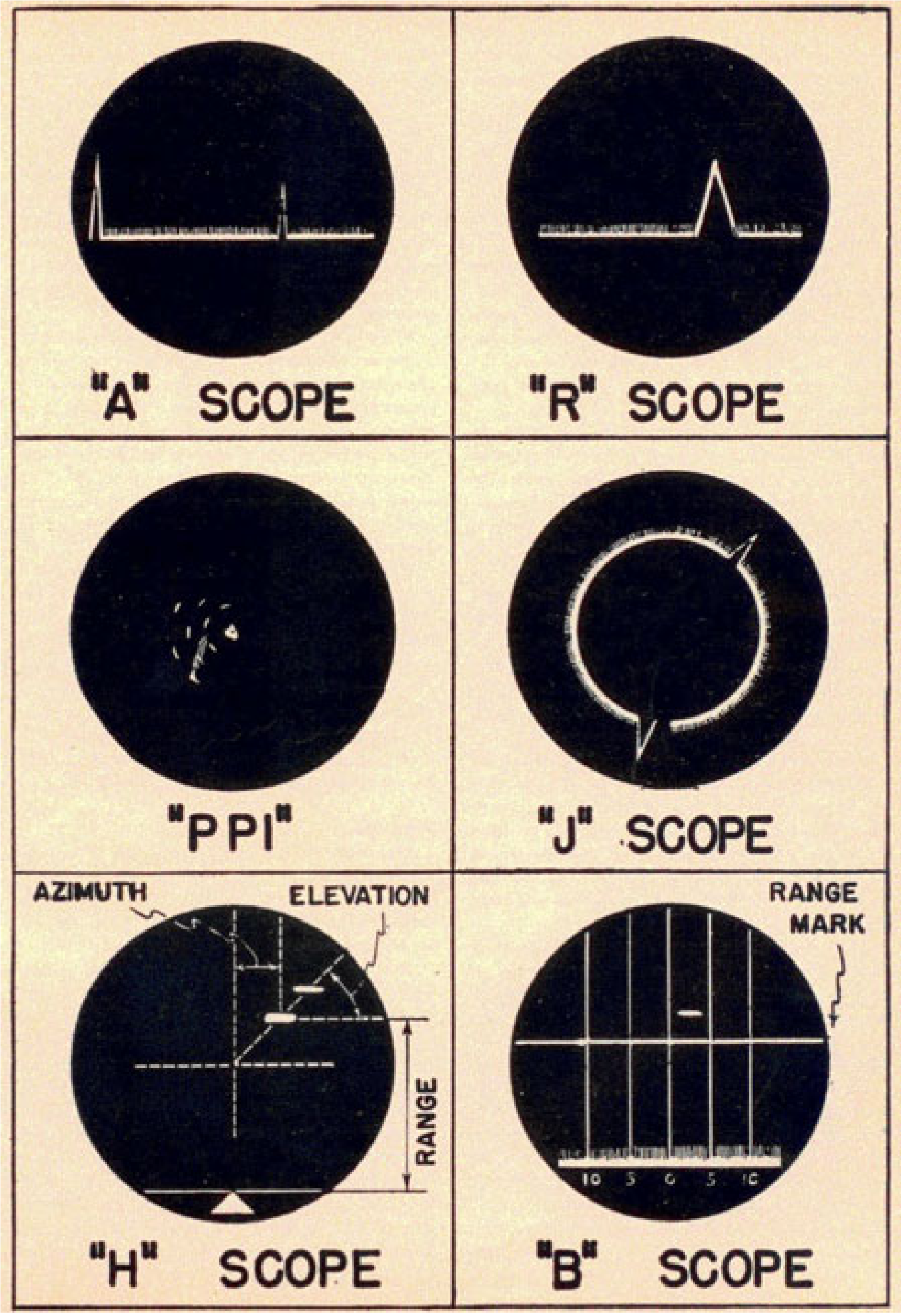

Figure 1-40. Scope presentations.

keying the transmitter, called, naturally enough, the *keyer*, is used. The keyer is also known as the *modulation generator*.

The modulation generator *keys the transmitter, forming pulses of definite duration and at regular intervals*. The definite duration is called the *pulse width* or *pulse duration*, and the number of pulses every second is called the *pulse repetition frequency* or the *pulse repetition rate*.

The modulation generator also controls the start of the sweep. Why is this necessary?

You remember that range is determined by measuring the time taken by the radio waves to leave you, travel out, reflect from an object, and return. In other words, you measure the total time between those occurrences.

You recall that the keyer turns the transmitter on and off to form the pulses. If it can also he used to start the sweep every time at the same instant the transmitter pulses or at the same time after the transmitted pulse, each blip will appear at an identical spot on the time base every time. Fortunately, it is not difficult to utilize the keyer to do this. It does this second job by sending a *synchronizing pulse* to activate the indicator. *Synchronizing* means that the pulse makes the sweep start always at the same time. This is also called the *synch pulse*. Thus, in addition to its other functions, the *keyer furnishes the synchronizing pulse, which starts the sweep at the same definite time with respect to the transmitted pulse*.

The sweep may not start at the same time as the transmitted pulse. By knowing how long the start of the sweep is delayed you can figure in that time in calculating the range. In some sets, range is determined by changing this time delay until the Consequently, while the receiver is receiving the transmitter is not transmitting, and vice versa. The transmitter uses the antenna only while it is transmitting (during this time no echo can be received), so it is possible to let the receiver use the same antenna while the transmitter is off. In that way, the weight of antennas needed, and the difficulties in tuning them are reduced. In addition, we have assurance that while receiving the antenna is pointing in the same direction that it was pointed when transmitting. Certain advantages, therefore, are gained by using the same antenna for both purposes.

However, this arrangement presents one difficulty. If the receiver and transmitter are both connected to the same antenna at the same time, the receiver will be unable to carry the load; hence means have been provided to disconnect the receiver from the antenna while the transmitter is sending out the pulse, and reconnect it when the transmitter shuts off. This switch is called the *reprod* (receiver protective device), or the *TR box* (for transmit-receive), or the *duplexer*.

If you are interested in nearby targets, this switch must operate very rapidly. A delay of only one forty-thousandth of a second in re-connecting the receiver would cause you to miss any targets within about two nautical miles. There are no mechanical switches which will work fast enough for this, so electrical switches are used, switches which have no moving parts except the tiny electrons in a tube. To work properly the duplexers must he tuned carefully. The technician should be called upon to do this.

Summary.

Let us review the action again, and follow the course of a single pulse. As the wave travels out from your ship (see fig. 41), the action will be stopped from

blip is moved to the center of the sweep. You can then measure the amount the sweep was delayed and know the range.

You will find the same basic units in practically every radar set. Often several, and maybe all of them, will he in the same box or cabinet, but they are always represented in some form.

The duplexer.

Most radar sets have large, bulky antennas. This is necessary in order to obtain good bearing accuracy. The transmitter, you remember, must he "coupled" to the atmosphere if it is to transmit its energy. The receiver, too, must he "coupled" to the atmosphere if it is to receive any of the reflected energy.

You recall that you transmit in pulses, and receive the echo while the transmitter is not sending.

time to time so that you can see how far the dot has traveled on the scope.

As the pulse leaves the transmitter, (1), the dot starts at the left side of the tube and traces out the shape of the pulse. When the pulse has traveled half the distance to the target, (2), the dot has completed one-fourth of its travel. As the pulse strikes the target, (3), the dot has traveled but half the distance to the place on the scope where the pip will appear.

As the echo, (4), moves toward your position you can see that the dot must travel the remaining distance an the time base before the pip is formed. When the echo, (5), reaches the antenna the radio receiver detects and amplifies the energy, which, when applied to the vertical deflection plates, causes the pip

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to be traced. Therefore, the time base actually measures the total time for the pulse wave to go out and return as an echo to your position. Because the speed of wave travel in each direction is the same, the scale on the scope can be calibrated to give the true range directly in yards or miles.

Broadly speaking, there are five parts involved in radar apparatus: the transmitter; the antenna, duplexer, and transmission lines; the keyer; the receiver; and the indicator or indicating devices. Of course, you must also have the required power supplies and controls in addition to the five basic units.

The transmitter is used to generate very short pulses of electrical energy which are radiated out

From the transmitter the energy flows through the transmission lines to the antenna which may he highly directional and concentrates the radio energy into a narrow- beam. As the wave travels out into space, reaches the target and returns as an echo, the scope traces a line along the screen forming the time-base. The echo strikes the antenna and is detected and amplified by the radio receiver and applied to the indicator scope in such a way that it causes the pip to appear on the time base.

Since the same antenna is used for both sending and receiving, you must have a receiver protective device to guard the receiver from the powerful outgoing pulses. By using the so called *duplexing equipment*

into space.

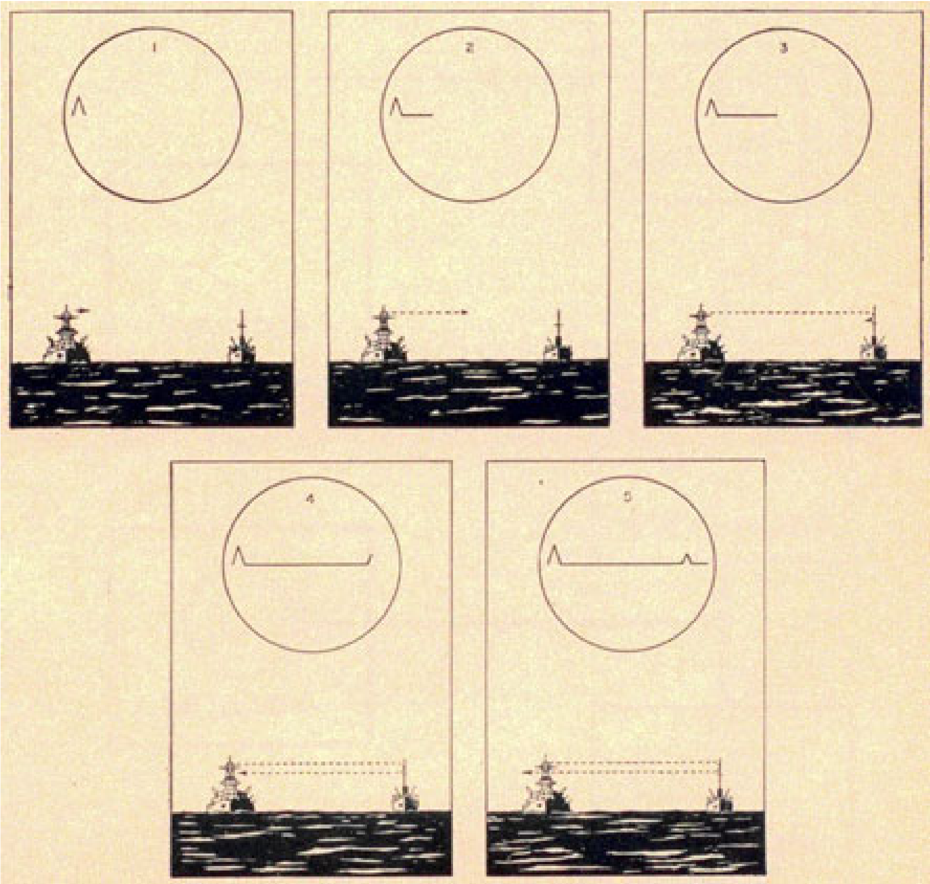

Figure 1-41.

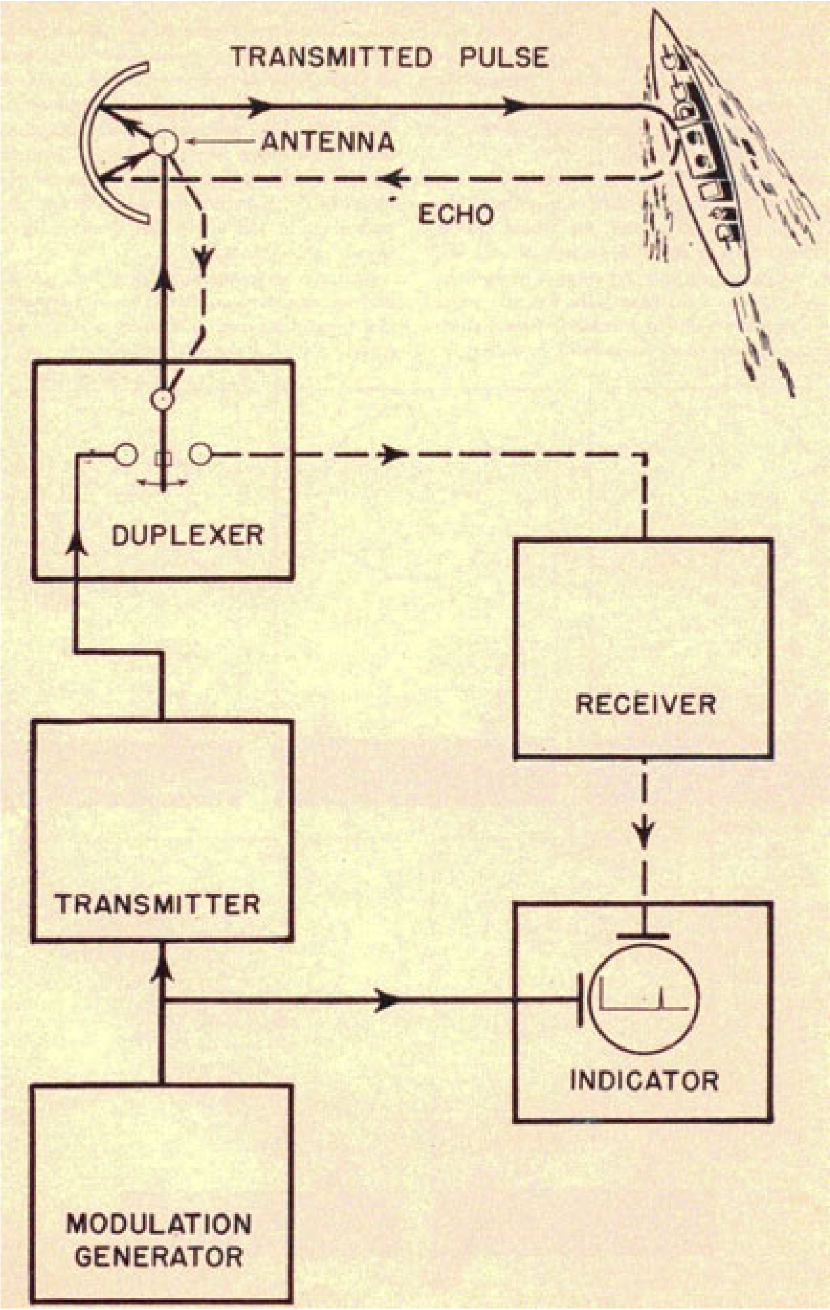

Figure 1-42. Block diagram of a typical radar system.

GENERAL RADAR PRINCIPLES

(which might he compared to a simple valve), you can keep the heavy flow of outgoing power away from the receiver. When the echo is received, the duplexing equipment works in reverse and forces the greater portion of the received signal into the receiver-indicator channel. The block diagram should assist you in fixing these component units of the equipment in your mind.

GENERAL RADAR CHARACTERISTICS

There are some common characteristics of air-search, surface-search, and fire-control radars than can be summed up as follows:

Air-search radar.

Long-wave radar	"P" frequency band
Antenna	Bedspring (curtain or flat)
Maximum range	Average 100 miles
Minimum range	Relatively long
Bearing resolution	Poor, due to wide beam
Range resolution	Poor, due to wide pulse
Pulse duration or width	Long
Fade zones	Observable
Accuracy	Expected range measurement error on 75-mile scale of PPI and

However, bearing and range accuracies are comparable for all fire-control radars. The average expected error in range measurement is from +/- 15 yards plus 0.1% range to +/- 40 yards. The average expected error in bearing measurement is from +/- 2 to +/- 4 mils (+/- 1/10 degree to +/- 1/5 degree).

FACTORS AFFECTING RADAR RANGE

Maximum range factors. In order to give you some reason for the variation in range performance of radar sets, we shall list the factors affecting the maximum range of any radar:

1. Wave length.
   a. Long wave length radar is best suited for air search.
   b. Micro wave length radar is best suited for surface search.
2. Size of target.
3. Height of target.
   a. Height of mast for surface target.
   b. Height of plane for air target.
4. Target presentation (target angle).
5. Material of target.
6. Height of antenna.
7. Output power radar.
8. Sensitivity of receiver.
9. Atmospheric condition.
10. Type of indicator ("A" scope most sensitive).
11. Pulse repetition rate (determines maximum range scale that can be used).
12. Beam concentration.
13. Condition of radar equipment.
14. Operator's technique and skill.

Minimum range factors.

There are also factors affecting the minimum range. They are:

HOW DOES RADAR DETERMINE ALTITUDE?

When enemy planes appear it is necessary to know their elevation before putting the antiaircraft guns into action against them.

"A" scope using scotch tape scale is +/- 1 mile.

Note: SM radar is an exception to the above.

Surface-search radar.

Micro-wave radar	"S" or "X" frequency band
Antenna	Dishpan or barrel stave
Maximum range	Approximately the line of sight.
Minimum range	Relatively short
Bearing resolution	Relatively good
Range resolution	Relatively good
Pulse duration or width	Short
Fade zones	None
Accuracy	In general better than that of air-search radar. For specific sets see Part 4.

Fire-control radar.

Fire-control radars vary so much that it is difficult to generalize about them. For characteristics of individual sets the reader is referred to Part 4.

How can this be done?

Position angle and range method.

At short ranges (up to several miles), the most accurate way to find the altitude is by calculation

1. Pulse width,
2. Receiver recovery time.
3. Height of antenna.
4. Receiver gain setting.

using the angle of elevation (or position angle) and the range to the target. The antiaircraft fire-control set is equipped to do this.

How does this information-the range and position angle-give you the elevation? For every size position angle, there is a definite ratio of the vertical side opposite this angle to the slant range. This ratio is called the sine of that angle. Tables which list values for all angles are available. As soon as you find the position angle and the range, look up the sine of the position angle and multiply this ratio (the sine) by the range (the slant distance to the plane). In some of the later radars you can even make the set do this calculating for you. *The elevation equals range times sine of the position angle.*

The foregoing method works well for short ranges, but is not satisfactory for longer ranges. At a few miles range, you can get the elevation accurate within a very few feet, perhaps within 25 or 30 feet, or even less. However, several factors cause the accuracy to drop off at greater ranges. One of these factors is that you cannot measure small position angles (angles of elevation) accurately. When you use vertical lobe switching, for increased position-angle accuracy), the lower lobe is distorted by the ocean when you try to measure small angles. Naturally, this reduces the accuracy. With some fire-control sets, you cannot measure position angles of less than ten degrees. Of course, the higher the frequency of the set the smaller the

Another factor reducing accuracy is the curvature of the earth. Close targets can be considered to be above the same flat surface you are on, even though this is not actually the case. The resulting errors are small for targets within range of antiaircraft guns.

The fighter director officer is also interested in elevation. He must get the elevation of planes at long ranges. Once an enemy plane is within antiaircraft range the main effectiveness of the fighter director is gone. His business is to direct his fighter planes on a course which will bring them within visual range of the enemy planes and effect an *interception* before the enemy gets within antiaircraft range.

It was found that phenomena known as *fades* could be used in doing the job. The use of charts indicating areas of these fades (called fade charts) is the long-distance method of finding elevation. It is not very accurate; the closest you can expect to come to the proper elevation is about 500 feet, but you stand a chance of making greater errors unless you are exceedingly careful. Errors of 15,000-20,000 feet may he made, and errors of 2,000-3,000 feet are common enough. Still, it is the best method available for getting elevations at great distances.

Air-search radar for altitude determination.

Air-search radar operators in times past often believed their sets were not operating properly, for the echoes from a plane coming in seemed to fade out more or less regularly, until the pip was no longer visible. Of course the pip became visible again before very long, but the fading out was disturbing.

This situation continued to puzzle the radar experts for some time. The strangest part of it was that not all planes faded at the same range. Then someone made the discovery that all planes flying at the same elevation (or altitude) faded regularly at the same ranges. Planes flying at a different altitude faded at different ranges, but any plane flying at a specific altitude was consistent: at any specific altitude all faded at the same range. A plane at 5,000-feet elevation, for instance, might fade at 72 miles, again at 50 miles, at 35 miles, and at 21 miles. All planes at this elevation faded at these same ranges. Planes at other elevations faded at other ranges. This was an important discovery. The fighter directors had long been seeking a reliable way to find the elevation of planes coming in. Here at last was a means by which that information could be obtained.

angles you can measure, but you must train the lobe a few degrees above the surface. A very distant plane will be only a few degrees above the horizon; hence, the difficulty of measuring a small angle arises.

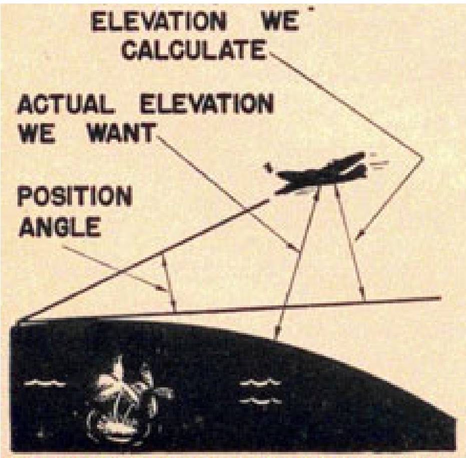

Figure 1-43.

The fade points were different for different radar sets, depending upon the frequency of the set and

height of the antenna, but once these fade points were found for a given set, they were constant. By sending our planes out at definite altitudes, the location of the fades zones for each elevation could be found and plotted on a chart.

Addition and cancellation of radio waves.

Before learning any more about fades, you should know why an echo from any type target should fluctuate in size, going from a maximum echo to a minimum or no echo, thence to maximum, and repeating this cycle as the target closes or opens. (A target is

One cycle contains 360 degrees. When a wave travels a distance of one wave length, it goes through one cycle, or 360 degrees. If the two paths of the waves are of different lengths, the two waves will go through different numbers of degrees in traveling from the antenna to the target.

If the two waves arrive as illustrated in figure 1-45, both starting a cycle at the same time, they are said to be *in phase*.

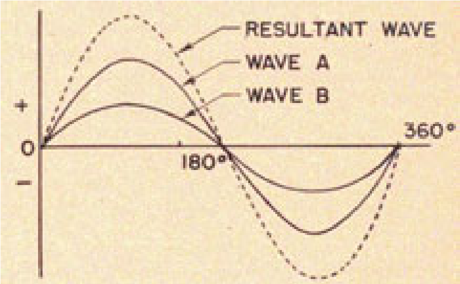

Figure 1-45. Two waves in phase.

closing when coming toward you and is opening when going away.)

Since the radar waves leave the antenna at such a number of different angles from the horizontal, some of the energy (or radar waves) will hit the earth or water, and bounce off (like rubber balls) at the same angle as they hit (fig. 1-44). Certain of these waves will strike the water fairly close to the ship and may reflect right back into the antenna as sea-return, while others, due to their decreased angle from the horizontal, will strike the water farther out, be reflected, and continue on. Others with a smaller angle, will strike the water still farther out, until finally they will begin to miss the water on the horizon altogether, and so must be traveling nearly parallel to the waters surface.

When this occurs you must consider what is known as the phase relationship between the two waves shown going out from the antenna in figure 1-44.

When the two waves are in phase, they are always acting in the same direction. They may be compared to two forces pushing on an object in the same direction; together they produce an effect as great as that of one force equal to their sum. The two waves in phase produce the same effect as one wave whose strength is the sum of the two, as shown by the dotted line in figure 1-45.

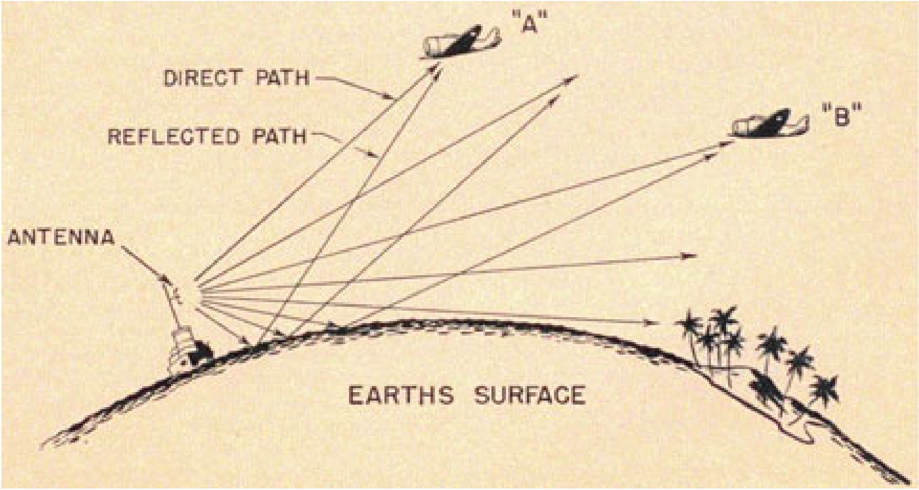

Figure 1-44. Determining elevation.

RADAR OPERATOR'S MANUAL

If the two waves do not arrive in phase, they are said to be *out of phase*. When this occurs, you must specify the amount they are out of phase. Thus, if one wave starts its cycle 60 degrees after the other wave, the two are 60 degrees out of phase. One wave may start a cycle anywhere from 0 degrees to 360 degrees after the other. Of course, if the two waves are 0 degrees or 360 degrees out of phase they are in reality in phase. Figure 1-46 shows two waves 60 degrees out of phase. It is seen that during some parts of the cycle the two waves are opposing, and during the rest of the cycle are supplementing each other. The resultant will therefore he smaller than it would be if the two waves were in phase.

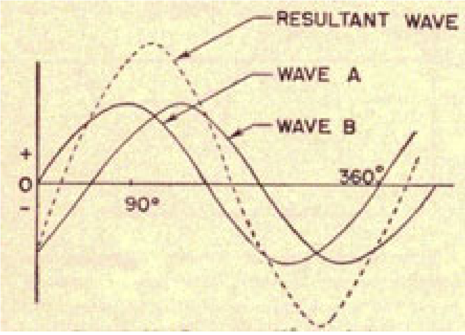

Figure 1-46. Two waves 60 degrees out of phase

. If the waves arrive as shown in figure 1-47 they are 180 degrees out of phase. In this case the two waves are always opposing, and if equal in strength they will cancel out and the result will be zero. Figure 1-48 shows two waves 270 degrees out of phase.

paths by wave forms similar to those used in the discussion on phase, for radar or radio waves will combine and behave in the same manner.

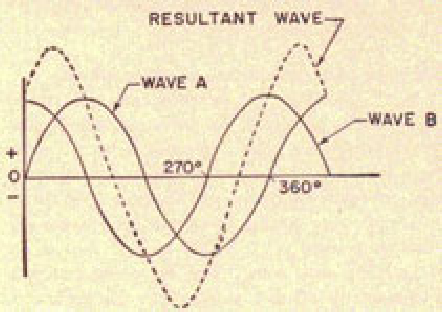

Figure 1-48. Two waves 270 degrees out of phase.

As these waves continue to leave the antenna, traveling paths of unequal length, there are places in space where the direct and reflected waves will be in phase. Thus, their forces add, as in the case of two forces pushing on an object in the same direction. In figure 1-49, plane B is in space where the direct and reflected waves reinforce each other. Therefore, the two waves striking it will add and return to its a maximum reliable echo. In radar these areas are called *maxima areas*.

At other places in space (see fig. 1-50, plane A) these radio waves traveling paths of unequal length will arrive at the target when they are 180 degrees out of phase. Thus, their forces will cancel, as in the case of two forces pushing on an object in opposite directions. Therefore, if a plane is flying through such an area, the two waves striking it will cancel each other and a weak echo, or probably none at all, will be returned. In radar, these areas are called *fade areas*.

The result of ground reflection is to break the single free-space lobe into a number of smaller lobes with

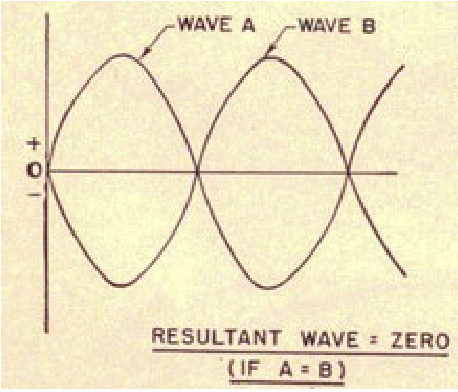

Figure 1-47. Two waves 180 degrees out of phase.

Now, let us redraw figure 1-44, representing the radio waves traveling along both the direct and reflected gaps between them. Figure 1-51 illustrates this effect.

Fade chart.

The above theory is applied to the construction of a fade chart showing the places in which you get cancellation (fade area), or reenforcement (maximum area) for a specific antenna. By use of this chart, it is possible to determine the altitude of planes quickly and without the use of mathematics. Fade charts vary in appearance, because each one has to be made to fit its particular antenna installation.

Figure 1-52 shows a typical fade chart. The line on the left side of the chart is marked off in feet of

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altitude. The bottom of the chart is marked off in nautical miles of distance, or range. The cross hatched lines on the chart represent the fade areas, or areas where the waves cancel, while the clear spaces represent the maxima areas, or areas where the waves add. The precise boundaries between the fade areas and lobe areas must be determined during calibration exercises.

The chart as reproduced here shows the theoretical maxima and minima areas, and is for practice in determining the altitude of a plane. It is not intended that this chart be used for actual altitude determination. Whenever theoretical charts of this nature are employed they should be checked when tracking planes of known altitude. Thus, the accuracy of the fade chart can be tested and any necessary changes made.

Let us take a hypothetical case in which the planes are assumed to be in horizontal flight and see just how their altitude is determined.

At 1000, radar reports large bogey (unidentified planes), zero-nine-zero true, range 90 miles. After several reports, the operator reports that the echo is fading, and finally at 1011 it disappears at zero-eight-six, range 56 miles. This indicates that the planes have entered a fade area, but you do not know which one, since it could be any one of three fade areas shown on the chart at that range. Therefore, it is necessary to mark each line on the lower side of each fade area at that range, since the planes are closing (points A, B, and C). (If planes are opening, the mark will be placed on top of fade area.) At 1014, radar reports

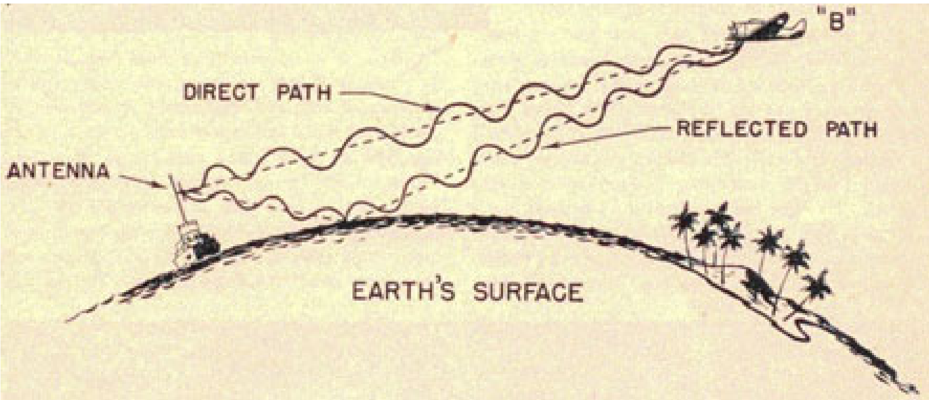

Figure 1-49

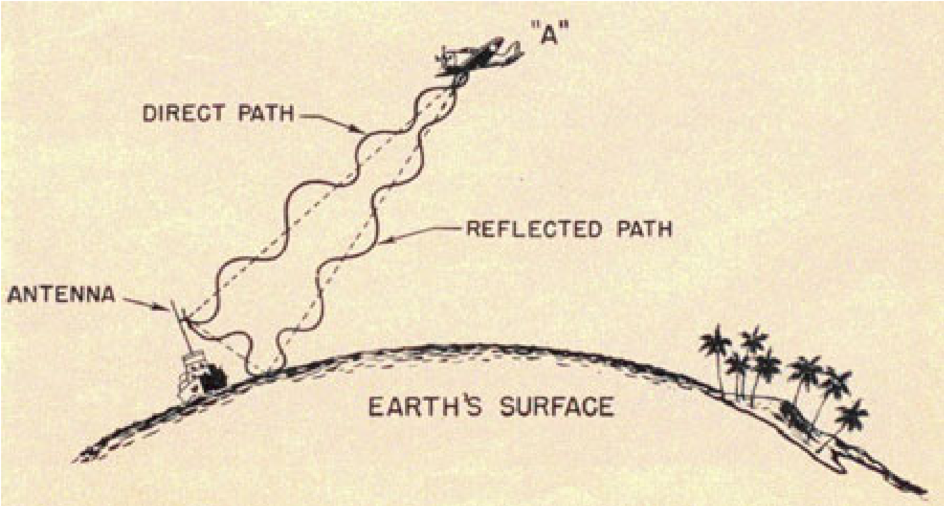

Figure 1-50.

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echo reappears, zero-eight-one, range 48 miles. This indicates that the planes have emerged from the fade area, so we place a mark on the top of each fade area at a range of 48 miles (points D, E and F). This is enough information for an estimate of the planes altitude. To find the estimated altitude, select the pair of points on the fade area which line up horizontally. The estimated altitude of the planes, indicated on the altitude scale, is 10,000 feet.

Later, radar reports that the planes have again entered a fade area at a range of 31 miles. Operator picked up target echo again at a range of 28 miles. This indicates that the planes have gone through a second fade area. By plotting the points as before on the fade area, you again find that the altitude is 10,000 feet. This verifies the original altitude estimated.

The use of a calibrated fade chart has just been demonstrated. These charts are calibrated to show not only the fade and lobe centers, but the exact size and shape of the area in spaces where planes will fade. The fade and lobe centers can be calculated mathematically, given the antenna height and wave length (see the engineering manual for air-search radar). However, the fade areas and lobe areas, i.e., the exact areas of radar visibility and radar invisibility, must be determined by observation using planes flying at various known altitudes. This is why fade chart calibration exercises are held from time to time. It is essential that your set be in excellent condition during the calibration exercises, because any change in the power radiated from the antenna will result in a change in fade zone size and re-calibration will he necessary. Conversely, the fade chart, when calibrated at a time when the radar is in good operating condition, serves as a first-rate device for checking performance. If the fade areas increase in size, the materiel condition of the radar has slipped below par.

One other thing which affects the size of the fade areas is the size of the target. Fade areas drawn for one small plane will be larger than those drawn for a large plane or many planes. In other words, the bigger the target the smaller the fade areas. Some fade charts show fade zones not for just one size target but for several.

Completely un-calibrated fade charts (showing only the positions of *fade centers* and *lobe centers*-points of minimum echo and maximum echo respectively) can be used fairly well even though the *limits* of the fade areas are not indicated, provided they have been drawn for the correct antenna height and wave length. If you have been unable to calibrate your fade chart, or if the materiel condition has changed considerably since the last calibration, you can still get a fairly good solution by estimating the range at

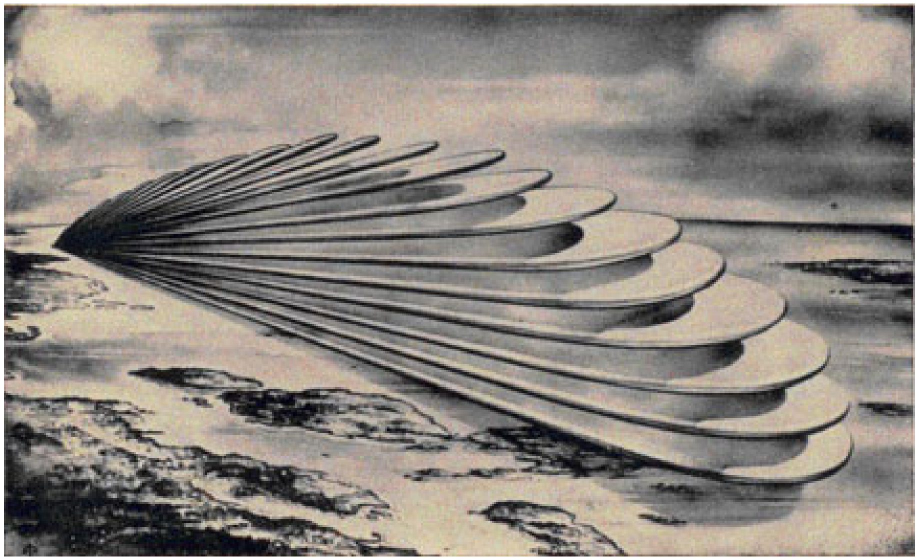

Figure 1-51.

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which a plane passes through a lobe center (and gives its strongest echo) and the range at which it is in a fade center. This use of the chart does not provide as rapid a solution of altitude in some cases as would be obtained with a calibrated chart, since it is necessary to wait until the plane has flown through a maximum and a minimum point. However, the condition of the radar and the size of the target need not be taken into account when using the chart in this way.

You have seen that in using the fade chart, the solution is reached in two steps. As the plane crosses a boundary between zones of visibility and invisibility (in other words, when it enters a lobe or fade) you get a number of possible solutions (one for each lobe) because you do not know which lobe the target is entering or leaving. When it crosses a second boundary, however, all solutions but one are ruled out on the assumption that the plane is in level flight. Under certain conditions it is possible to tell which lobe a plane is in at the instant contact is made. You can do this when the plane is picked up at very long range. Anything beyond 120 miles would be in the lower (first) lobe or else its altitude would be over 40,000 feet, which is unlikely. Look at your fade chart and see what the maximum expected range is for contacts in the second lobe.

Instantaneous estimates are also possible when the plane is detected at fairly short range: For example, suppose you have been on the air-search radar for twenty minutes and the screen has been "clara."

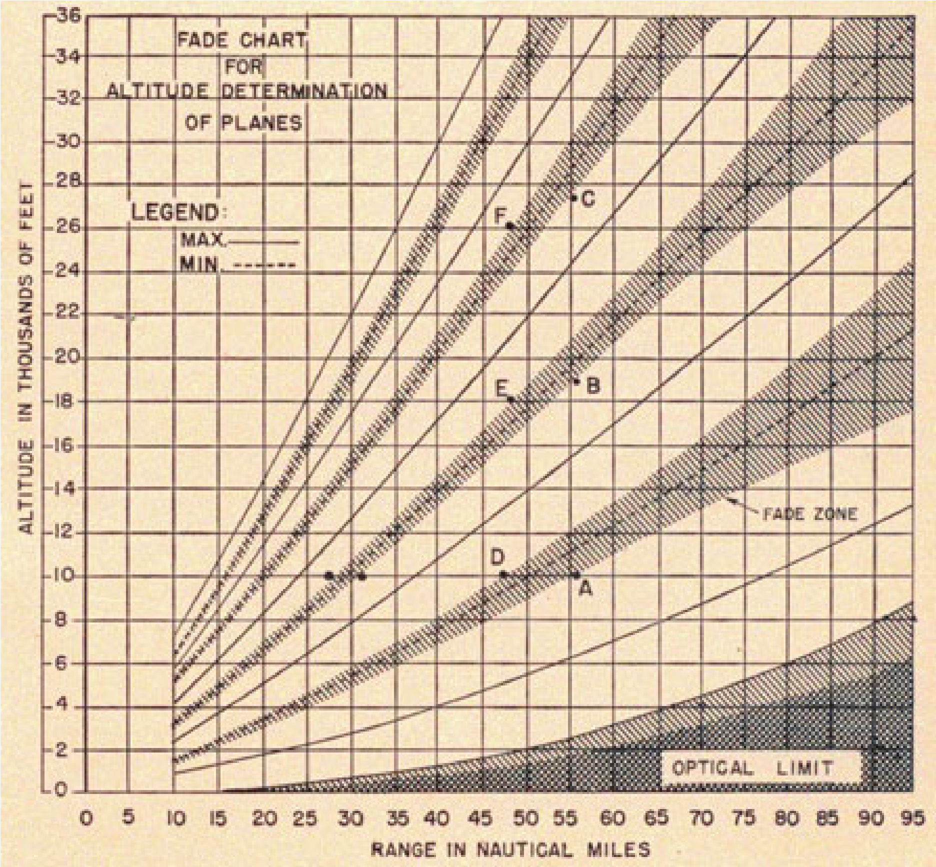

Figure 1-52. Fade chart.

Then if a contact arrears at a range of 20 miles you can reason that it is most likely at an altitude of 300 feet and entering the first lobe. The plane is not apt to be lobe, so immediate altitude estimate is possible. Constant use of fade charts will familiarize you with the certain capabilities and limitations of your radar.

SPECIAL USES OF RADAR

Actual operation in the Fleet has proved that radar may frequently be called upon for special jobs that are ordinarily not in the daily routine of the radar operator. It is well, therefore, for the operator to have a general knowledge of these special applications of radar so that he may carry out intelligently any special assignment when called upon. The operational technique recommended in each case is discussed in some detail in Part 3.

Navigation.

entering the second lobe at an altitude of 3,500 feet, because if it had made a horizontal approach at that altitude you should have detected it entering the first lobe at a range of about 65 miles. In fact, if the plane had been at 3,500 feet, you should have detected it at all times between the ranges of 65 miles and 24 miles. Similar reasoning rules out the possibility that the plane could be entering the third or fourth lobes, so the altitude must be about 300 feet and the plane must be entering the first lobe. This example

Because fairly accurate bearings and ranges can be obtained on landscapes with radar, it is frequently used as an aid to navigation. The PPI is particularly useful in this respect, because it gives a fairly accurate picture of the surroundings. It is obvious that the PPI can be of great value in navigation when visibility is poor. Buoys can be seen-on the PPI, as well as islands, jetties and shore lines.

With sufficient experience the radar operator may aid navigation by taking tangents on landscapes. This calls for considerable practice, but the method is approximately as follows: The operator swings the beam toward the island or land until pips just begin appearing on the scope. He then assumes that the effective edge of the beam is just striking the land, and swings the antenna on it about half the effective beam width. The center of the beam should then be on the edge of the land and the bearing can be taken. A range is then taken either on the edge of the land or the nearest point of land on that bearing, and a fix may be obtained. Tangents on low-lying landscapes are to be avoided as a rule, because the operator can never be sure that the tangent point is actually being detected. Practice in taking tangents will reveal other equally effective methods of obtaining fixes.

Spotting.

By training the antenna in the direction of the target, it is possible to watch the shell pip move along the time base. A shell in flight will give the appearance of a mouse running under a sheer, as seen on the "A" scope. When the shell strikes the sea, the resulting geyser of water gives an even better echo for several seconds. Do not try to range on the splash, try instead

illustrates not only one technique of altitude determination, but also the necessity for alertness on the part of an operator. If a plane is closing at three miles per minute and it flies in (low) under the first lobe, it may easily come to a range of 20 miles before an alert operator detects it. You can give the ship a maximum of seven minutes warning if you are on your toes, or less if you are not.

So far, only planes in horizontal flight have been considered. It is possible for a plane to

fly down a lobe so that it does not fade at all. Likewise it is possible for one to fly down a fade zone and escape detection for long periods of time. This accounts for an occasional plane getting in to less than the usual range of detection. It does not happen often and it is not done deliberately.

Before leaving the subject of fade charts, let us summarize briefly: To use the charts you must assume horizontal flight. Uncalibrated fade charts show the positions in space of lobe

centers and fade centers. They can be used as they are if drawn for your antenna height and wave length, but it is best to calibrate them (by working with planes at known altitude) to show areas in which a plane will be seen and areas in which the plane will be in a fade. The size and shape of these fade areas will depend upon two things: the materiel condition of the radar and the size of the target. The better the materiel condition the smaller the fade zones will be for all types of air targets. The smaller the

air target, the larger will be the corresponding fade zones. The fade chart can show fade zones for several sizes of air target. Calibration exercises should be conducted with the radar in the best possible materiel condition. The fade chart affords one of the most effective checks on the condition of the radar once it has been calibrated. If a plane is detected at extremely long range, or if it is detected at short range for the first time, it must be in the first

GENERAL RADAR PRINCIPLES

to estimate the range difference between the splash and the target.

In estimating this range difference, it is helpful to know the range width of an expanded "A" scope, the notch width, the width of a typical echo (expressed in yards) as seen on the "A" scope, and the range dimensions of anything else that can be used for comparison. If there is a scotch tape range scale on the "A" scope, it too can be used to estimate the range difference.

Fighter direction.

The search operator never knows when he will be called upon to aid in fighter direction. Although he may be on a destroyer or small craft, there is always the possibility that someone aboard his ship may be acting as a fighter director officer in an emergency. The operator should practice giving bearings and ranges rapidly and accurately on a large number of targets so that he will be able to handle this strenuous job if called upon.

FUTURE OF RADAR

Radar will play an increasingly important part in our lives during the period following World War II. It will be on the job then as now, protecting our lives, and making this a safer world in which to live. Read what David Sarnoff, president of RCA, has to say about the postwar prospects of radar:

> "Television and radar add new dimensions to radio. Wireless telegraphy was its first dimension, and broadcasting its second. Application of these new developments of radio to peace creates new fields of activity on land, at sea, and in the air.
>
> "Radio instruments will emerge from the war almost human in their capabilities. They will possess not only a sense of direction, but a sense of detection that will open new avenues of service. The radio direction-finder, which heretofore had only an ear, now also has an eye. The safety of aviation will be greatly enhanced, for the aviator will be able to see the ground through clouds or darkness. By the scientific application of the radio echo, the radio "eye" will avert collisions, while the radio altimeter will measure the altitude and warn of mountains ahead or structures below."

There is no doubt about it-radar is a coming field. Learn all you can about your equipment, its maintenance, and care. What you learn will be of use to you in the future.

Direction finding.

The radar receiver and antenna may be used as a direction finder to obtain the bearing of another radar or a jamming transmitter. It may be impossible to obtain the range of a radar or jamming transmitter, but bearing fixes from two receivers at separated positions may provide a fix. The receiver must be tuned to the same frequency as the radar or jamming transmitter in order to get an indication on the screen. The operator will see moving pulses, humps, or

other indications on the screen, and the antenna should be trained until this indication is at a maximum. There are several reports of ships making a rendezvous with other ships by this method when visibility was poor, or radio silence maintained.

Fire control.

The fire-control radar may he put out of order during an engagement, whereupon the search radars will be called upon to give bearings and ranges for fire control. The operator should be prepared to

handle this problem by knowing the range and bearing errors of the equipment. Constant check with fire-control radars will give the operator this information.

When shifting targets during an engagement some fire-control radars must be coached on the new target by the search-radar operator. The latter, having a complete picture of the situation, can easily and quickly coach on the fire-control radar with bearing and range information.

Version 1.00, 4 Sep 05

PART 2

GENERAL IFF PRINCIPLES

PART 2

GENERAL IFF PRINCIPLES

2-1

GENERAL IFF PRINCIPLES

INTRODUCTION

In this section we are concerned with a major problem: that of identification. Having detected a target and interpreted it to be a plane or a ship, how can you he certain whether the target is friendly or enemy?

Consider for a moment how ineffective a sentry patrolling an outpost in a war zone would he if he were unable to distinguish between the men attached to his unit and the enemy trespassers. There would he two courses of action open to him: he could either sound a general alarm for each person who approached his post, or he could allow everyone to pass unchallenged into the camp, assuming that they could he identified later. Such practice would inevitably lead to disaster. However, we are confronted with much the same problem in radar operation. Radar is a long-range sentry that reports the presence of all trespassers, and is constantly on the alert for enemy ships, planes, and other objects.

Of course, the customary Navy methods of identification are still available. But in challenging by blinker light and by high frequency radio voice codes, the sender must disclose his position to the challenged contact. Both methods have the added disadvantage of range limitations.

In the accounts of the earliest tactical use of radar, all the evidence points to a lack of suitable means of target identification as the most serious limitation of radio detection and ranging.

Need for IFF and history relating to its development.

fighter rarely ventured far from home. Thus, it could be taken for granted that all planes approaching from across the Channel or flying in from the North Sea were enemy. However, the Germans soon abandoned their daylight assaults because they could not stand the appalling losses of men and aircraft. This was the first real setback that the Luftwaffe had encountered in its wholesale bombings.

Driven from the sunlit skies, the Nazis resorted to all-out night bombings, relying on darkness to shroud the destruction-laden bombers from the deadly sting of the Spitfires and Hurricanes. But this freedom from effective fighter opposition did not last long. Radar, constructed so compactly that it could be taken aloft in night fighter planes, unerringly sought out the almost invisible black bombers. When the keen-eyed pilots had jockeyed their planes into gun range, the Nazis were met with a rain of hot steel pouring at them out of the darkness. As the night fighters were sent up in greater numbers, the toll of enemy planes increased, *but so did the problem of target identification*. Before he opened fire, the RAF pilot had to be certain that the pip was from an enemy plane and not from a comrade's plane (and the pips looked the same on his scope). The old problem of identification grew steadily more troublesome and the need for a solution became more critical.

It was the RAF's switch from the defensive to the offensive that really brought the need for an infallible system of identification to the forefront. Realizing that merely guarding their tight island fortress was not enough, the RAF had launched its own offensive. Soon British raiders were making the trip back and forth across the Channel.

We are indebted to the British for development of the equipment that we so sorely needed. They had their own system of radar and its use helped in no small measure to save England in her gravest hour of peril. Still, at the outset, one serious limitation threatened to destroy radar's effectiveness, and that was this same problem of identification-the problem of IFF, *Identification, Friend or Foe*.

While the Luftwaffe was striking and the RAF was strictly on the defensive, the British radar operator had no identification problem, for his own

The Nazis, foiled and confused by the magic of radar, started dispatching their bombers close on the tails of the returning British squadrons. Unaware that German planes were trailing them, or, in some cases even flying among their formations, the British pilots led the Nazis safely through the defensive radar network unrecognized. The radar operators were unable to distinguish between a pip from the British planes which they were expecting and one from a Nazi, for there was no observable difference in the appearance of either pip. The first indication of the electronic sentry's failure to detect the enemy was the

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crash of bombs on factories, hangars, and other objectives. The British defenses were taken completely by surprise. The raiders withdrew before the antiaircraft guns could get into operation and before a fighter could get off the ground. The radar operators were powerless to stop the leak so long as the British carried on their own cross-channel operations.

Faced with realization that the radio locator was totally ineffective in coping with the new tactics, the English radio technicians working feverishly developed and put into production in one short week a type of identification radar, the first IFF unit. This special unit produced an identifying pulse that appeared on the screen along with the target pip. With this new equipment installed in the RAF planes and working in conjunction with land-based and shipborne radar, the operator was at last able to identify the target as friendly by observing whether the additional signal accompanied the target pip. Since the enemy aircraft were not equipped with the special unit, they could immediately be identified as hostile simply by the lack of the distinctive identification

transponding unit). In the cabinet housing the BL are two separate sections; the *interrogator* and the *responsor*. The section that challenges the unknown craft is called the interrogator. As its name implies, it interrogates or questions the units carried by friendly aircraft and surface vessels. The responsor section of the BL intercepts the answers to the challenge.

The interrogator is a low-power transmitter that creates a short-duration pulse of radio energy which is beamed out as a pulse of radio waves. This pulse from the BL or BN is the questioning signal or challenge directed at the detected craft, and although it is slightly wider (i.e., it lasts a few millionths of a second longer) than the radar transmitter pulse, its strength or power is weak in comparison. From your study of basic radar you will recall that it was necessary to send out a very high-power pulse in order to get even a small reflection off the target in return. The "echo principle" is not used by the BL. A different principle is involved. All that is required from the interrogator is enough power to send the questioning radio waves to any craft within the range of the search radar. Of course, the signal must

pulse. The addition of IFF made radar a relatively trustworthy long-range sentry that could distinguish between friend and foe.

PRESENT UNIVERSAL SYSTEM-MARK III IFF RADAR

The addition to the radar family, IFF, is designated as the "B" group, with different models indicated by a second letter; however, an "A" precedes the two letters on the name plates of airborne equipment. The modifications and improvements on the original system, the ABA (also referred to by the "Mark" designation) or Mark I, have been numerous, but the basic principles of operation are similar. In this discussion attention is centered upon the Mark III, the IFF system in use today.

Equipment and operational characteristics.

Mark III IFF consists of two distinct units. The BL or BN is the set we will consider first. It is really just a "baby radar" with some of the regular radar units missing. It has an antenna, a duplexer, a transmitter, and a receiver, but no modulation generator or indicating device, using instead the radar set's timing system and indicator. The BL is a shipborne or land-based recognition radar placed alongside the search radar. It is the function of this unit to "challenge" the detected target and identify it as either friendly or hostile. Only friendly craft answer the challenge (providing they are equipped with the necessary be strong enough when it reaches the target for it to be picked up by a special "receiver" carried solely by friendly air or surface craft.

The BL transmitter transmits on a narrow band of frequencies, the upper end of which overlaps the band employed by air-search radar transmitters. Different bands are necessary to prevent the air-search operation from interfering with the identification. Without this separation a maddening jumble would result, similar to that heard on any radio when more than one station is picked up at the same spot on the dial. That situation is undesirable in radar when one station is the interrogator and the other the search transmitter. The pulse rate of the BL is generally the same as the pulse rate of the radar transmitter, and the two units start to pulse synchronously, since the "keyer" of the search radar that triggers its own transmitter also triggers the BL transmitter.

Invariably the BL is connected to the available model of shipborne radar designed for air search. There are several reasons for the BL being used in conjunction with air-search gear: first, air-search radar can detect both air and surface targets; second, the range of search for this type of radar is longer; and third, the size and construction of the antenna pedestal and framework wake it possible to fasten the *directional* BL antenna system to the air-search antenna structure (SA, SC-1, SC-2, SC-3, and SK all incorporate the directional BL antenna). The BL

antenna sends out its spurt of radio waves in a wide but somewhat directional beam to the object on which the search beam is trained. Thus the questioning signals are sent out to the craft that has been detected at the bearing toward which the antenna is pointing. The BL radiating section serves to emit the challenging pulse as well as to intercept the answer from the unit aboard the challenged craft which indicates it is friendly. But it is not practical to mount the directional BL antenna array on the barrel stave or spinner antennas connected with surface-search radars. Either a "stove pipe" or a "steering wheel" antenna is used with these latter types, which are *non-directional* because they are merely single dipoles. The three types are shown in figure 2-1 below.

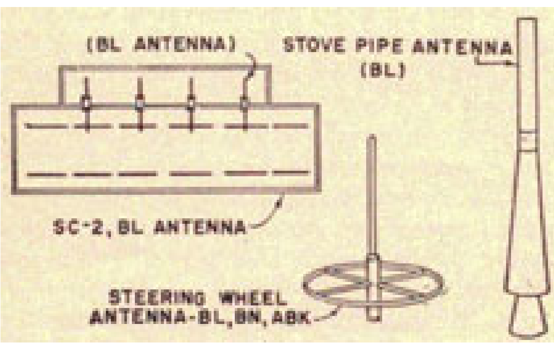

Figure 2-1. IFF antennas.

The BN is identical to the BL insofar as component parts and operational characteristics are concerned. The main differences between them are in size and power output. The BL is the larger, more powerful unit used with air-search radar on the larger ships; the BN answers the need for a compact, lower power unit that will operate on both large and small craft in conjunction with the surface-search radars, The BN is generally connected to the non-directional type of antenna.

The second section of the BL, the *responsor*, functions as the receiving or "listening" apparatus; it receives the answer to the challenge. The responsor is a powerful receiving set which is always tuned to the same frequency as the interrogator. By the action of the duplexer, the of amplification or gain to the required level. After the signal is amplified, it is changed or converted into a positive voltage (or negative output which is required by some search radars) available for application to an indicator unit. Since the BL has no indicator unit of its own, the indicator of the search radar must picture the IFF output. In order to make the identification signal visible, the receiver delivers the impulse to the A scope of the search indicator. The positive signal voltage is applied to the lower vertical deflection plate of the C.R.T. Attracted downward by the momentary positive signal, the electron beam is pulled down, tracing a pulse below the time base line. This is an important point to remember: the identifying signal appears *below* the trace line, and by appearing there, lessens the possibility of confusing IFF indications with target pips which invariably appear *above* the trace line.

The unit of the IFF communication system that receives the challenge and sends back the identifying pulse or "answer" is termed the *transpondor*. The transpondor is most commonly referred to by its abbreviated designations: the BK, or shipborne model, and the ABK, or airborne model. (The BK and the ABK are practically identical in all respects.)

Since the transpondor was originally designed for aircraft use only, the ABK-BK is small, compact equipment weighing about 30 pounds. Housed in the cabinet are two sections comprising the receiver and the transmitter. In its operation, the transpondor is entirely automatic once it has been turned on. Although it can tell a ship or ground station that the plane carrying it is friendly, it can not furnish the pilot of the plane carrying it the same information about the ships below him. Only the ship or land station finds out that it is a friendly airplane. The BK in your ship hookup is not associated in any way with your own radar equipment. The plane equipped with ABK may not have any other radar at all, but if it should have, it has no connection whatsoever with

antenna is switched from the BL transmitter, at the end of the pulse, to the BL receiver, allowing each to work in its turn without interference from the other. The weak reply signal is amplified or strengthened by the receiver into a sizable signal. With the "remote" IFF (receiver) gain control (located on the control panel of the search-radar set) the operator can adjust the amount

its IFF unit. The ABK, located in the plane, is connected to a small non-directional antenna which intercepts the questioning signals from any direction. An antenna with this characteristic of picking up signals sent out from any direction is very desirable, for the safety of the craft depends upon its ability to receive the challenges from all points of the compass and send back the answers which appear as the identifying pips on the scope of the search-radar indicator.

The steering wheel dipole antenna is generally used with BK in shipboard installations, and a single dipole is utilized for aircraft (ABK) installations.

The ABK receiver tunes the same wave band on which the BL transmits. If the ABK were tuned to the low end of the band, would it receive the challenge from the BL interrogator transmitting on the high end of the same band? Obviously it would not, and on account of its inability to receive the question, there would be no answer forthcoming. To make your identity known to all interrogators, you must he able to "hear" each of them separately. If only one fixed frequency were used by all BL and all ABK equipment, the receiving of challenges would be like listening to a crowd of people all talking at once. In such a case, many of the questioners would be either indistinguishable or blocked out entirely. To avoid this, BL equipment is tuned at different points on the frequency band. But how can the ABK receiver pick up those different signals if it is tuned to a fixed frequency? Only the challenges from interrogators transmitting at the same frequency would be intercepted.

In the past when you tuned in your radio, you twirled the dial of your receiver from one end of the broadcast band to the other, catching brief

a pulse; actually it generates the reply or response to the challenge. The generated pulse is radiated in all directions from the non-directional antenna. This pulse is a low-power transmission, but it is much more powerful than the echo signals of ranging. The pulse rate of the ABK will he the same as the rate at which the BL sends challenges to the ABK. At the completion of each reply pulse, the transmitter rests, and after a recovery period the receiver comes on again to receive another questioning signal; upon receiving the signal, the triggering is repeated. If the receiver picks up no challenges, the transmitter will remain at rest because of the lack of the triggering voltage.

A common tuning section serves to tune the receiver and the transmitter across the wave band. Whenever the receiver is tuned to the frequency of an interrogator, the transmitter (tuned to the same frequency) responds at the same frequency as the challenger's.

Coded response.

Finding that a single IFF response might be imitated

snatches of programs until you found the one you wanted. The tuning action of the transpondor is quite similar. The tuning mechanism itself is automatically operated by a motor-driven cam, so that the band of frequencies is being continually swept. Each time the tuner reaches the high end of the frequency sweep, the device flies back to the low end and repeats the operation at a slow, constant rate. Approximately two and a half seconds are required to tune from the low frequency to the high frequency end of the band. Another half second elapses while the tuning device flies back to the starting point at the lower end of the hand. This means that one tuning sweep requires a total time of three seconds. Therefore, the receiver is tuned for a short time to each interrogator frequency along the band every three seconds. The ABK receives a challenge at the instant its frequency matches the interrogator frequency, and this match takes place at regular three second intervals (as long as the search-radar antenna remains trained at the target with the BL on).

Whenever the ABK tunes in a EL challenge, it automatically amplifies and converts the signal into a strong voltage, which is applied as a "kick" to the transmitter section of the transpondor. The transmitter is normally at "standby," -not functioning- while the receiver is on constantly. As soon as the positive signal voltage is fed from the receiver, it immediately triggers or turns on the transmitter and the receiver is turned off or blocked, This ABK transmitter functions like any other transmitter. It creates

by the enemy, the designers of the transpondor found a way to make the answers more complicated. With three circuits available for connection to the ABK transmitter, and with the characteristics of each such that the pulse width can be changed, means are provided for *coding* the replies. When the ABK transmitter is honked up by the cam system to one circuit, the pulse width is seven microseconds, the *narrow* or *short* pulse; connection to another circuit produces a 21 microseconds, or *wide* pulse; the third blocks the transmitter from answering, resulting in the "blank" response or "silent" period. Each time the tuning sweep begins, the cam connects the transmitter to one of the circuits. If the narrow pulse circuit is first hooked in, any challenge received in the three-second period will be answered by a narrow pulse. At the completion of the sweep of the band, the narrow pulse circuit is disconnected by the cam action and the wide pulse circuit is connected to the transmitter; all responses in this three-second period are wide pulses. During the next three-second interval, if the blank circuit is cut in, there will be no responses, for this is the silent or "skip" period.

The three different responses are made into combinations or codes, a code consisting of any four signals, pulses, and/or blanks. Twelve seconds are required to send or complete the code of four characters which are made up into some of the following combinations: narrow, narrow, wide, blank; or narrow, narrow, wide, wide. When the blank is part of the

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code, an additional three seconds exists between two pulses,-the skip period. The timing in the first example above would be first, a narrow pulse; three seconds later, a narrow pulse; three seconds later, a wide pulse; six seconds later, a narrow pulse, etc. The code is repeated every 12 seconds, and will continue so long as the antenna points at the target when the IFF switch is on. With six separate codes available, the particular code to be used can be selected by means of a six-position switch on the control box. (The six codes used are highly confidential and will not be described in this book.)

A special response feature is provided on the ABK, -a fourth circuit separate from the coding set of three, that gives an 80-microsecond, very wide pulse. This reply is controlled by a separate switch, the emergency switch which is protected by a guard that must be lifted before the switch can be snapped on. When the switch is thrown to the emergency position, the 80-microsecond pulse, regardless of the position of the code switch, is sent out to all challengers at three-second intervals, and is the signal of distress.

One cycle analysis of IFF operation.

Given an understanding of the makeup of the Mark III IFF system and the function of each unit, let us trace, the operation of the equipment through one complete cycle.

Assume that the operator has detected a target bearing 080 degrees, range 60 miles, and has identified it as a plane. His next step is to determine whether it is enemy or friendly. Keeping the antenna trained on the target, he turns on the IFF switch to put the BL interrogator into operation. He is now in the position of a sentry challenging a trespasser. (Normally the IFF switch is off and the BL is in standby, i.e.: the transmitter is resting and the receiver is effectively triggering the transmitter. This delay may consume from three to five microseconds.

(For this example let us assume that the pilot of the detected plane has set his ABK to the code position that would give the response: narrow, narrow, wide, wide). The echo returns to the search antenna where it is intercepted and fed to the receiver tuned to pick it up, the search receiver. The echo signal finally appears as a pip showing above the trace line. At the instant the target pip is completed, the narrow response is intercepted by the BL antenna (the search receiver will reject this signal just as the BL receiver had previously rejected the echo signal due to differences in frequency). The signal, delivered to the responsor, is amplified and then converted to a positive voltage, whereupon it is supplied to the indicator unit of the ship's radar. The trace is pulled downward, forming *below* the trace line a narrow pulse that is just to the right of the target pip (owing to the longer time required for the two-way IFF communication). The IFF indication is much stronger than the pip from the plane because it is the result of a stronger signal. The downward indication is connected to the pip it identifies, making it possible to associate the proper target with its identifying signal.

The action just described is repeated each time the search transmitter pulses, so long as the ABK is tuned to the BL output. The narrow IFF signal is easily distinguished from the wide, as it appears to be just slightly wider than the target pip of one plane, and when measured along the time base its total width covers approximately *one mile* of range. After appearing on the screen for about a tenth of a second, the narrow pulse disappears (the ABK has tuned past the BL frequency so it is no longer triggered by your interrogator unit), and not until three seconds later does the IFF signal again flash on the screen. Since the narrow signal is next in the code series, a narrow pulse flashes briefly on the scope, three seconds after the first, and soon

disconnected from the ship's radar indicator). The BL pulse and the pulse of the search gear travel out to the target at the same speed. Both beams strike the plane surfaces and reach the antenna of the transpondor. Part of the waves from the search radar are reflected, and a small part of the challenge pulse is bounced back, but it so trivial that it dies out almost immediately.

Of the two wave fronts striking the ABK antenna, only those from the BL can he tuned in by the ABK receiver; the ship's radar transmission is above the frequency range of the ABK. (This is presuming that the ABK has tuned to the BL frequency at this instant). The echo from the search pulse has begun its return trip before the ABK receiver succeeds in disappears, leaving only the target indication.

Three seconds later the wide pulse appears on the indicator. After another three-second wait a wide pulse again flashes downward; it appears for a fraction of a second and then it, too, disappears. Three seconds afterward, a narrow signal flashes, to begin anew the coding sequence. Thus the code is repeated time after time (so long as you continue to interrogate) with each code requiring a space of 12 seconds. As the wide IFF signal is the result of the 21-microsecond pulse, it is about four times as broad

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as the target pip of one plane and is roughly two times the width of the narrow IFF pip. In other words, the *wide* indication measures almost *two miles* in width along the trace line. (All measurements are made from the leading edge of the signal to its outer edge, and it is a good idea to make an estimation to determine these values because the pulse is on the screen for such a short time). A person experienced in operating radar and observing the IFF codes can identify the code appearing on

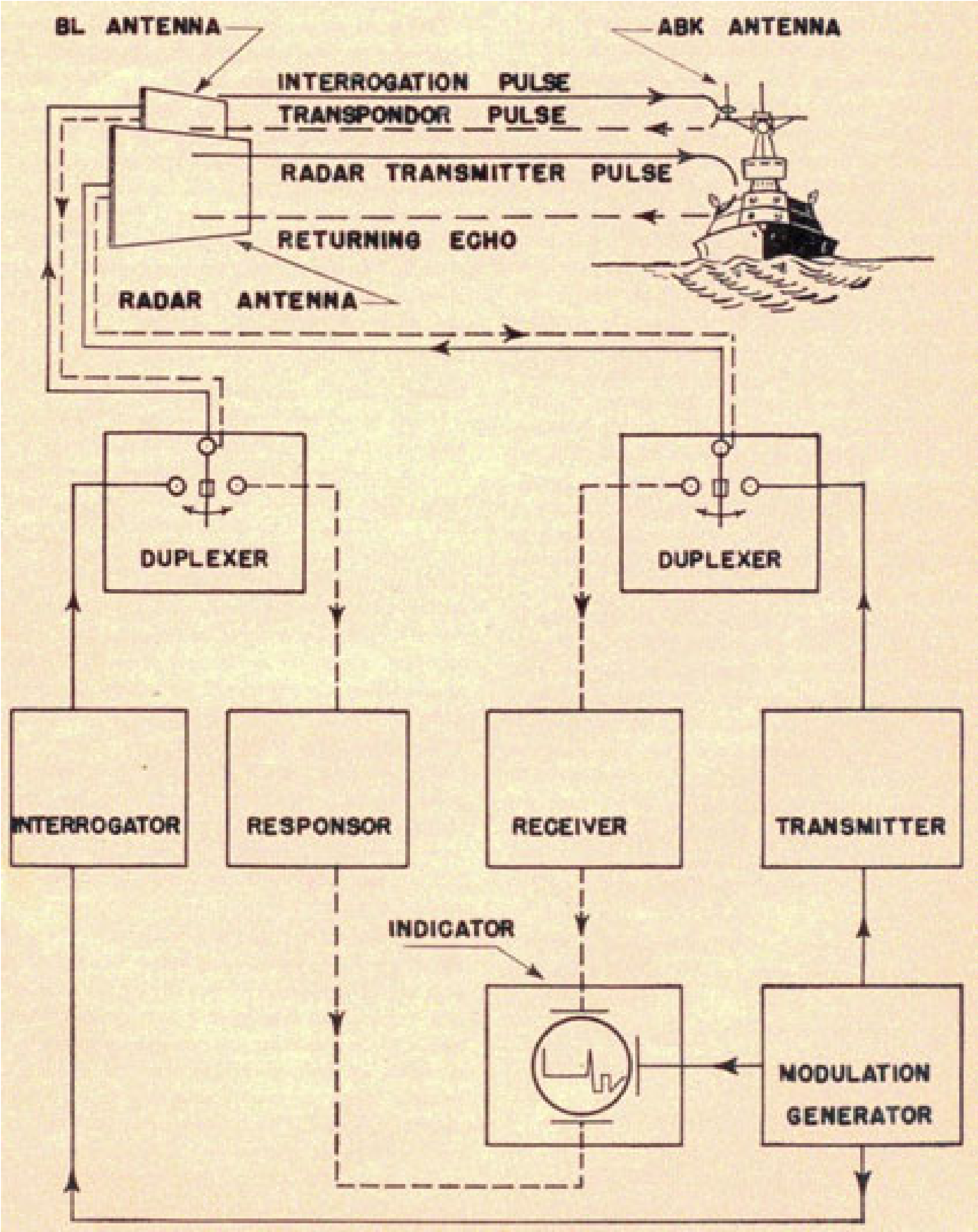

Figure 2-2. Block diagram of a typical radar system with IFF.

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the indicator in at least 24 seconds; the time of two coding periods.

Both the Germans and the Japanese have had some luck in building an airborne machine that triggers off from the challenges of our interrogators. The first models gave only the one-size signal in answer. With our ARK-equipped aircraft giving any one of a possible six codes, the operator may encounter little trouble in detecting which was the false response of the hostile planes. By establishing specific periods of operation for each of the six codes, the system of frequently changing the password minimizes even further the possibility of the foe hitting upon a signal that might he confused with the friendly combination. For instance, from 2400 to 0600 all surface craft and aircraft in a specified area will set the BK and ABK code switch to Code No. 3, and all operators of search radars are instructed to report all but the No. 3 response as unfriendly during the same period. Then, during the hours 0600 to 1200 Code No. 6 will be the selected password; thus, throughout the day, the acceptable answer is varied. (The radar officer keeps the men informed of the code to be accepted for any corresponding hour). The system of changing codes throughout the day or week is similar to changing passwords regularly to reduce the possibility that an enemy will discover the password and get by a sentry.

As soon as a target is identified as friendly, the IFF switch is turned off and the identifying signals cease, for the ABK is no longer being triggered. To continue to challenge a plane or ship is undesirable after it has been identified, especially near hostile areas, for the IFF signals travel over long distances and continuous questioning of one plane might enable the enemy to pick up the signals in the powerful receivers that are constantly combing the air for our transmissions. The B!. should he kept in a standby condition, ready to challenge when the IFF switch is turned

IFF will also appear on the PPI indicator, but identification is more difficult if it is used instead of the "A" scope. As illustrated in figures 2-3, 2-4, and 2-5, it appears as a bright spot, or spots, depending on the antenna speed and ABK code used, and will always be outboard of the target indication.

Failure to get a response from any target that is challenged *generally* indicates that the target is hostile. This is not always reliable, however, due to ABK failures, or the chance that the unit may be turned off. From this fact, it can be seen how vital trouble-free IFF operation is to our ships and planes that rely on the BK and ABK to identify them to other ships and ground stations. While interrogating a target, it is possible to receive other IFF signals from the bearing at which the antenna trains without detecting a target pip. This is due to the longer effective range of IFF.

Reporting distress with IFF.

If the target being challenged sends back a very wide response that flashes below the trace every three seconds, it is the emergency or distress signal. However, before reporting the signal as an emergency, it is a good practice to cheek to be certain that it is the extremely wide distress signal and not the wide pulse of the coded combinations. One reliable method of checking is to measure the distance that the IFF indication occupies on the time base. Since the ABK sends out an 80-microsecond wide pulse on emergency, the signal will pull down about seven miles of the trace line. Comparing this seven-mile wide signal with the two-mile wide signal of the code series, you can see that there is no excuse for mistaking the true distress signal. Not only is the emergency pulse about four times as broad as the wide reply, but the distress signal also appears at the regular three-second interval,-a succession of very wide signals.

Therefore, if you observe a wide pulse as the first

on.

The following are, in brief, the main characteristics which aid in recognizing an IFF signal on the A scope:

1. It appears below the time base.
2. It is a stronger or longer indication than the target blip.
3. It is a broader signal than a one-plane target pip.
4. It is to the right of the target it identifies.
5. It appears at regular or periodic intervals and remains on the scope for only an instant.

IFF response and are in doubt about its being the distress signal, continue to watch the replies closely for nine seconds. If three wide pulses appear in succession, it is the real thing, the emergency signal, for the six codes are made up in a manner that makes it impossible for the 21-microsecond reply to appear three times in succession (it can appear twice, and then some narrow pulses are thrown in). It is a good practice to make one or both checks before reporting the signal as "distress," It must meet these specifications: (1) at least a seven-mile wide pulse, and (2) pulses

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GENERAL IFF PRINCIPLES

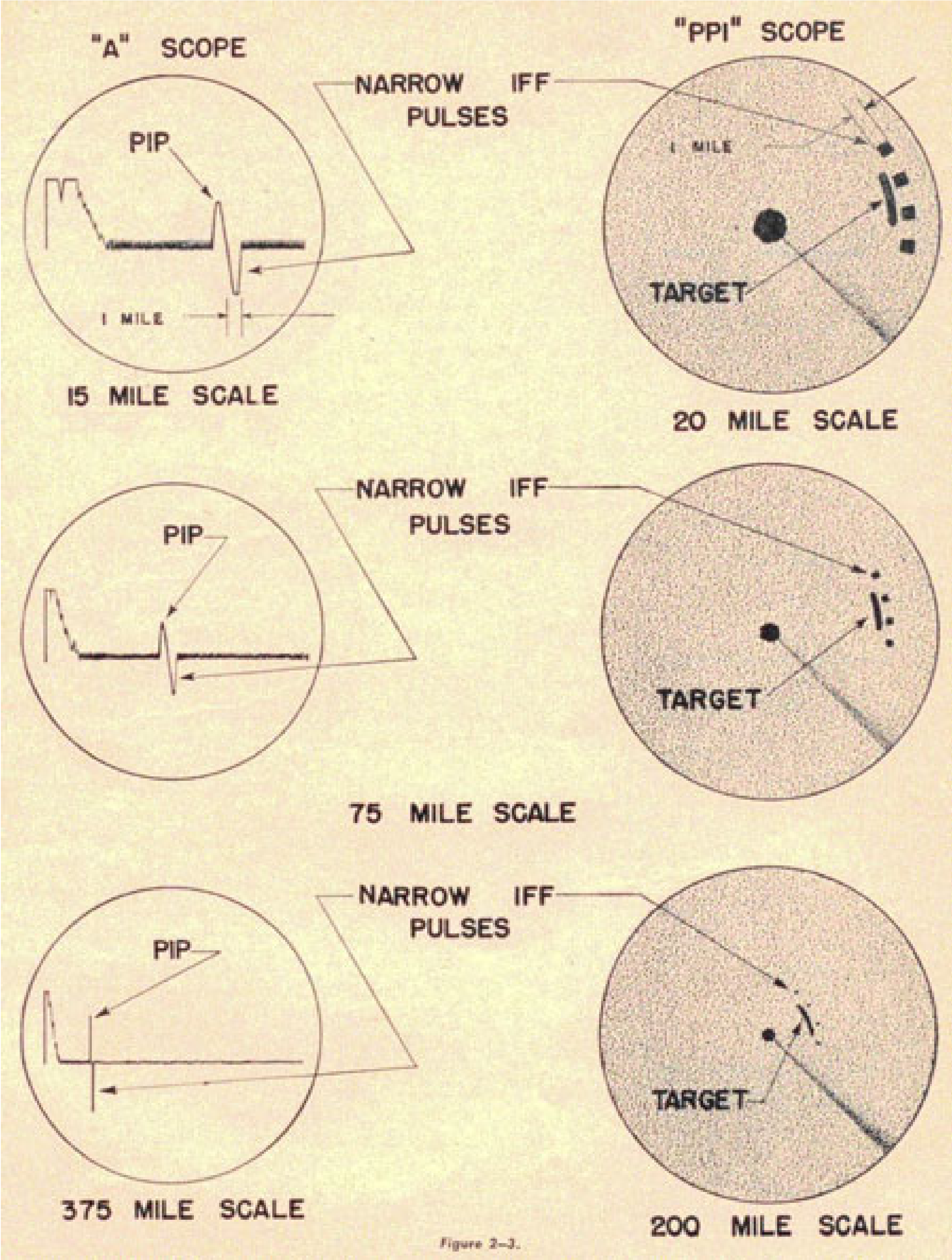

Figure 2-3.

RADAR OPERATOR'S MANUAL

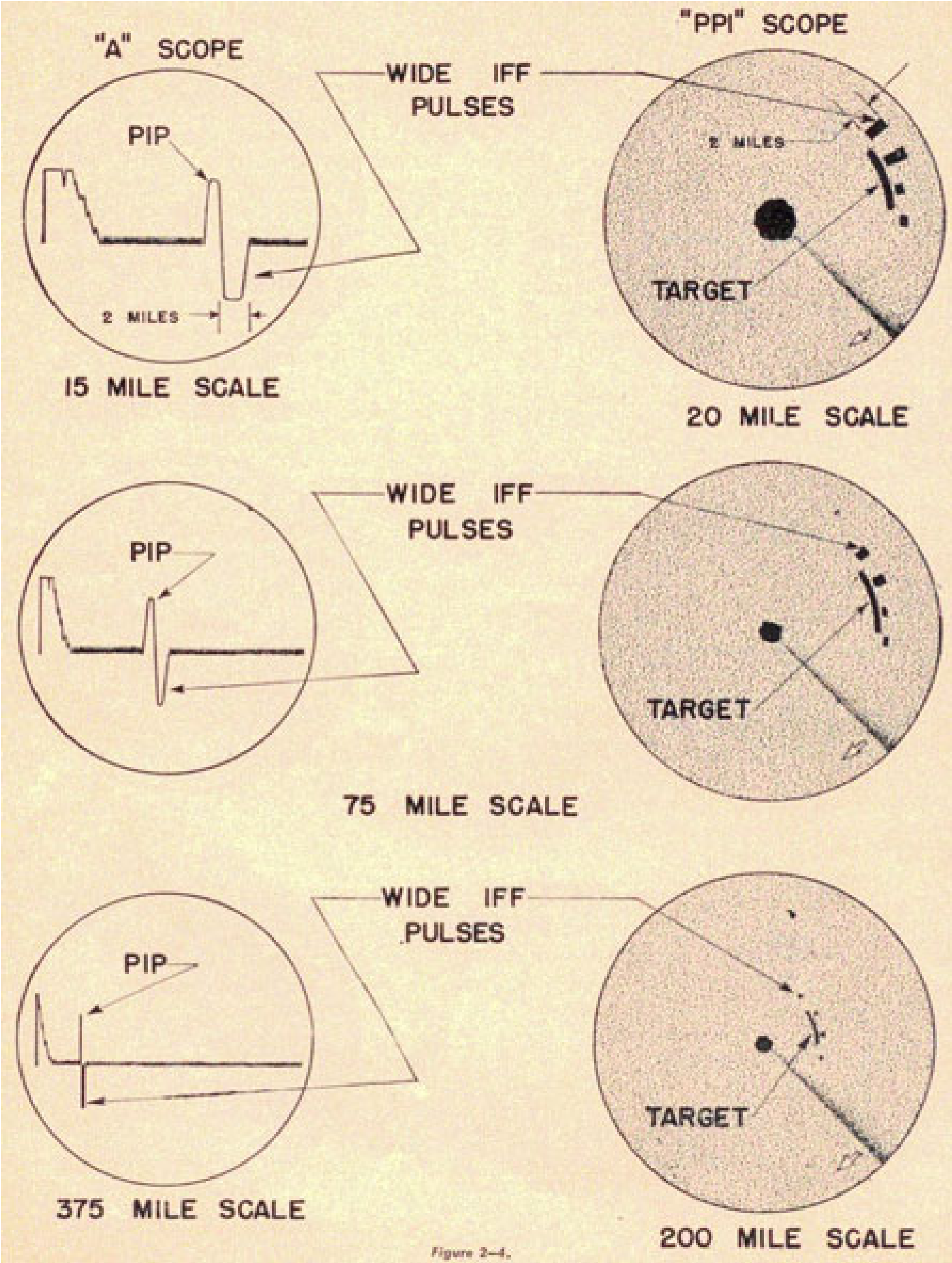

Figure 2-4.

GENERAL IFF PRINCIPLES

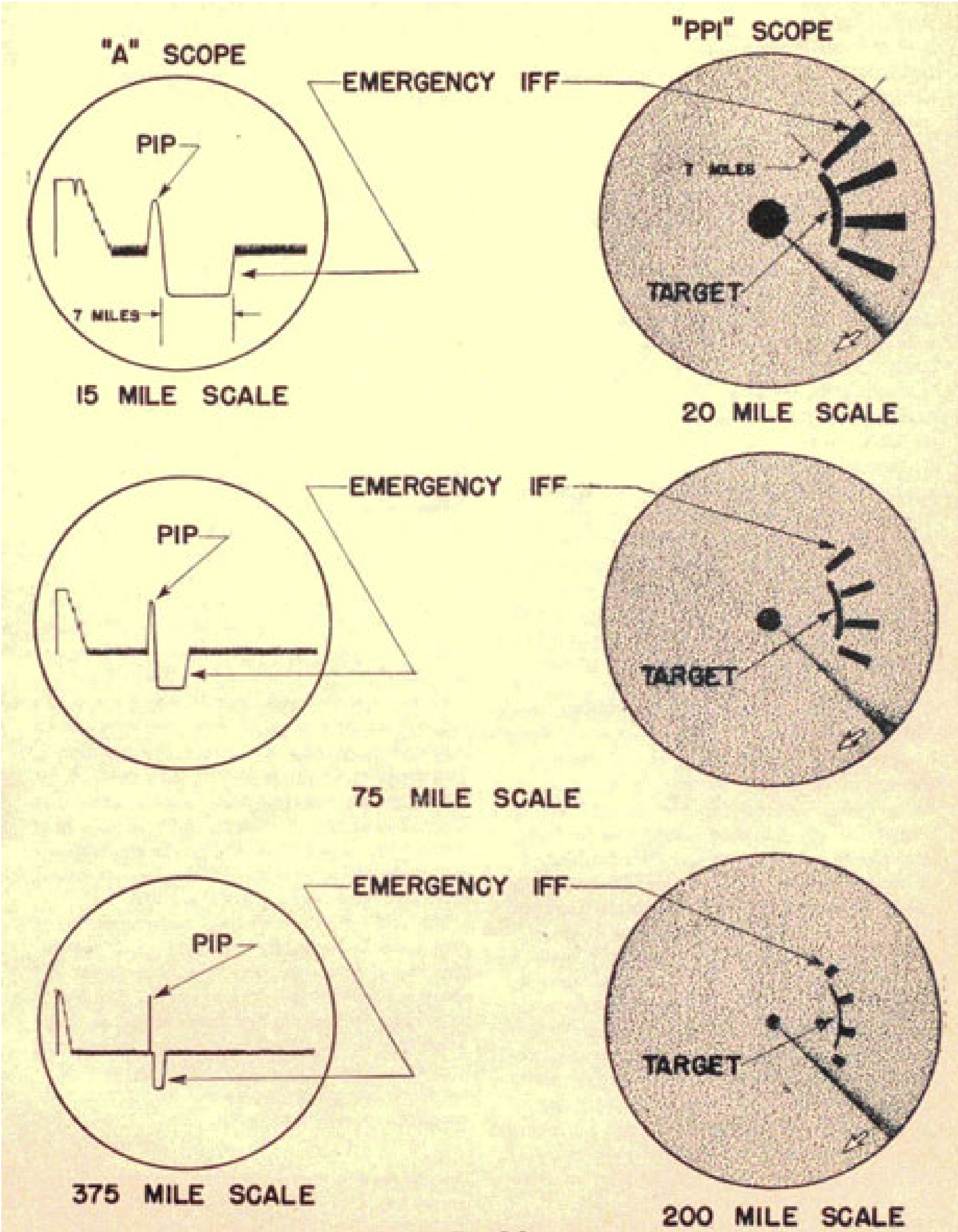
"A" SCOPE
"PPI" SCOPE
EMERGENCY IFF
PIP
7 MILES
TARGET
15 MILE SCALE
20 MILE SCALE
EMERGENCY IFF
PIP
TARGET
75 MILE SCALE
EMERGENCY IFF
PIP
TARGET
375 MILE SCALE
200 MILE SCALE

Figure 2-5.

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flash on the screen three seconds apart with no variation in width.

Second only in importance to identification is this application of the Mark III IFF system to the transmission of distress signals. Whenever a pilot is in trouble and finds that he must make a forced landing at sea or in a trackless jungle, he cannot turn on his radio to send out an S.O.S. to his home base, if he is in a war zone. He does not want the enemy to intercept his distress call. Generally, he does not know what his exact geographical location is so his message would be of little help in any event. But by using the emergency position on his ABK he can show his location to the search-radar operator. Consequently, he switches to Emergency" on the ABK control box. Very likely a radar operator somewhere is searching the horizons. Detecting the plane, he turns on the IFF to identify it and on the screen sees the extremely wide signal flashing below the trace at three-second intervals. Quickly reporting the bearing and range of the emergency signal, the operator continues to track and report the plane until both it and the emergency signal disappear from the screen. The rescue plane or ship is promptly dispatched to the last reported hearing and range position near which the plane has probably crashed. The use of IFF to indicate distress is responsible for the rescue of innumerable pilots and crewmen of disabled Allied planes and ships.

The emergency signal is often the indication that a plane has lost its way. When the distress signal is picked up at a land station, the information is reported to the nearest air base. The apparently aimless course indicates that the pilot has lost his bearing and communication silence may be broken in an attempt to contact and give directions that will set him back on his course. In ease all attempts to establish contact by radio fail, a plane is dispatched to the lost plane's position to lead it to safety.

range without the target being revealed by a pip. But you can range on the signal by judging where the leading edge of the pulse appears on the time base and reporting that figure along with the bearing to the C.I.C. The target can be plotted from the reports on the movement of the signal as it flashes at different ranges along the time base, with the range always figured to the point at which the pulse starts to pull down. Pointing the antenna to maintain maximum strength of the emergency signals provides more accurate bearing information on the craft in trouble.

Always be on the alert for the emergency signal, for prompt and accurate reporting of this distress appeal may be the means of saving many lives,

SECURITY

Necessity of safeguarding IFF security.

Because we are entirely dependent on the ABK-BK equipment to determine which of the ships and planes detected by radar are friendly (at long range), it is of vital importance to keep the apparatus or any information about it from falling into enemy hands. A similar unit installed in enemy planes and ships could deceive us completely and would render our own radar entirely unreliable.

Security of information must he strictly maintained to guard against such a possibility. IFF equipment is even more confidential than the rest of radar materiel. The regulations applying to strict observance of the rules of security regarding radar must be emphatically followed in matters pertaining to IFF. Certain parts of the ABK related to the coding operation and the code itself, while classified "Confidential," are treated in much the same way as "Secret" material.

The ABK is safeguarded by measures similar to those taken to protect the bombsight. It is removed

Using the emergency signal to signify anything unrelated to distress may have its disadvantages. In recent operations a carrier task force decided to use the signal as the code for "the enemy has broken through our outer battle line." Considerable confusion developed when the pilot of one of the patrolling aircraft threw on the emergency switch because engine trouble was forcing him down. Unaware that the signal was just the ordinary indication of distress the force was hastily prepared for an attack that never materialized.

When you are identifying one target, an emergency pulse may appear on the scope at some greater

from the plane at the completion of the flight and placed in a guarded vault for safekeeping. If it should be necessary to leave the unit in the planes, an armed guard must be maintained over the craft carrying the equipment. Even then, certain confidential parts without which the unit cannot operate are removed from the ABK as an added safeguard.

The destructor: the safeguard against enemy possession.

But there is still the problem of maintaining the security of the equipment when planes fly over enemy

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territory. There is always the possibility of aircraft being forced down or shot down with the ABK itself still in an undamaged or repairable condition. To guard against this contingency, a detonator is installed in every ABK unit. This detonator or "destructor" is an explosive charge inserted into the side of the cabinet. When exploded, it can destroy the insides of the unit so completely that it is impossible for the enemy to determine what the resulting wreckage originally was. Composed of thermite, the charge can be set off without rupturing the case, and though the terrific heat melts everything already blown up, it cannot injure the pilot who sets it off nor can it damage or set fire to the plane. It does a thorough job of guarding the security of this important IFF unit.

The designers made certain that the detonator would function regardless of the fate of the crew of the airplane. The pilot has two switches to push to explode the demolition charge if he must land on hostile ground, so that the foe is rewarded only

convoy by visual means or with his own radar, he switches the ABK to Code No. 3. The search operator observes that he is no longer getting No. 1 response; instead, he recognizes the new code as No. 3. The bearing and range of the significant signal is reported at once. Long before the search radar could detect the convoy's approach, the ship has obtained useful information, and transmission of this advance word has been accomplished without breaking radio silence.

Reference was made previously to the possibility of following a plane's or ship's progress by observing the IFF signals changing bearing and range. In plane-tracking operations, the target pip often disappears, and in spite of all the operator's efforts, he is unable to bring the antenna to bear on the target with sufficient energy to produce a pip. Consequently, he must report that he has lost the target.

But the operator could have turned on the IFF and checked near the bearing at which the pip faded out. It is possible that the radarman could again have

with a picture of destruction when he attempts to investigate IFF. If all the crew are killed, an impact switch does the job for them. It sets off the destructor when the plane crashes. The greatest care must be taken when handling the detonator itself, for this small bomb can spell doom if carelessly handled outside the equipment. Numerous safety precautions are taken to prevent the ABK from being accidentally destroyed, as for example. in a rough landing. If the impact switch were not disconnected immediately before landing on the home held or on a carrier, such a landing would set off the charge.

ADDITIONAL USES OF IFF

By taking advantage of the adaptability of the ABK, the air forces have extended the range over which radar search information can be gleaned. In using only one of the six codes to indicate friend or foe, and assigning the remaining live to meanings of a special nature, the airmen scouring the seas for the enemy can relay invaluable information without informing the enemy. Suppose that Code No. 2 is to signify "sighted sub," Code No. 3 "sighted convoy." Code No. 4 "sighted enemy battle force," Code No, 1 "normal operating position-okeh-friendly, etc." The radarman on the carrier or land station tracks the patrol planes with the interrogator turned on. After he loses the target pips, he continues to receive the No. 1 coded signal, possibly from beyond 100 miles, which tells the operator that there is nothing to report so far. But as soon as one of the pilots sights, let us say, a found the target pip when he trained the antenna to get the strongest IFF responses. In case the target pip failed to reappear, due to the extreme distance or adverse conditions, the operator could continue to track the aircraft by following the IFF signals.

By checking the range of the nearest edge of the IFF signal on the time base, an approximate range on the target can be obtained; bearing readings are taken when the pulse pips flash at maximum strength. Therefore, the distances over which a plane can be tracked are greatly extended, and the likelihood of losing the target is materially reduced when IFF is used as a tracking aid.

IFF has its fade zones in which the signals disappear, just as in the case of air-search radars. So continue interrogating, a "bogey" may become "friendly" when he gets out of an IFF fade zone. IFF fades, however, do not occur in the same places as the fades of the associated radar. Consequently, the target may be fading while the IFF response is very strong; next, the target signal may give a strong indication while the IFF has faded out completely.

The ABK transponder is the universal IFF unit used by the Army, Navy, and Marine Air Forces and by the Allied Navies and Air Forces as well. Needless to say, the chief use of IFF is for identification of ships and planes. In our all-out anti-submarine campaign in the Atlantic. it was extremely useful when ships were detected by radar and later sighted by lookouts, the appearance of the low-lying ship superstructures resembling surfaced submarine conning towers. Any indecision as to identity was dispelled as soon as

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the target was challenged by the BL. The absence of the IFF response was the signal to press home the attack. This reliable system saved our forces afloat from the confusion that often brings about self-inflicted losses. IFF has been especially helpful to our own submarines and PT boats, enabling them to operate with some assurance that they will not be attacked by our destroyers.

EQUIPMENT FAILURES

The ABK transpondor is the most carefully and frequently checked and tested of all the radar equipment. It is inspected after each flight to make certain that it is in perfect condition. Parts of the set, such as the tubes, are replaced at the end of relatively short operating periods to insure against equipment failure due to old or worn-out parts. In spite of all the precautions taken to prevent ABK failures, the unit does develop troubles that render it inoperative. There is no visual indication that the equipment is not operating. However, there is an outlet jack into which earphones can be plugged. All the pilot (or operator aboard ship that is being challenged) hears is noise of the transmitter turning on and off, providing that the set is being triggered at the time. Yet there is always the chance that silence in the phones indicates that the unit is not being challenged, rather than not working due to some failure.

The BK or ABK must always be checked when there is a possibility of being challenged by one of our own planes or ships. Causes of trouble and failures in early models of the ABK have been studied, and modifications in the later sets have eliminated many of the shortcomings. Since the Mark III IFF system is composed of special vacuum tube circuits and mechanical gadgets that are all subject to failure, the chances are that only about 80% of all our ABKs function correctly all of the time. That means that what we sometimes skippers have, on occasion, launched torpedoes at a friendly destroyer. Tragedies such as these have been variously attributed to equipment failure of the ABK units, failure of the interrogators, failure to turn on the ABKs, or no IFF installation.

Conditions of poor visibility due to weather conditions or time of day prevented the lookouts from correcting mistaken decisions on the status of sighted objects. Enumeration of these unfortunate incidents gives some idea of how important it is to have the IFF system working properly.

LIMITATIONS OF MARK III IFF

So far the IFF has seemed to be an easily understood, smoothly operating piece of equipment, and so it is, if all of the parts work as well as they appear to on paper. This unfortunately, does not always hold true. Because of the obvious value of identification radar, it is important to understand thoroughly its capabilities and its limitations. It must be constantly borne in mind that Mark III IFF is an *aid* in determining friendly or enemy character of a target and cannot be relied upon to give 100% identification.

Non-directional interrogation and range identification.

A few examples will serve to show just how much you can depend on all indications given by IFF of a friendly radar contact. First, assume that you have discovered two surface contacts at the same range (8,000 yards) but on different bearings on your radar. One is friendly, and the other is enemy, but unfortunately you do not know that. The fact that all surface-search radars use the non-directional IFF antennas leads to further trouble. If you stop your radar antenna on the first contact, and challenge it with your IFF, you will get a response which will tell you that it is friendly. Then you rotate the radar antenna to the second contact, challenge it, and get a

think is an enemy contact is actually friendly. There is also the possibility that the transmissions of transpondors or interrogators may be blocked from some directions by either ship or aircraft structure.

In the Southwest Pacific, according to official reports, our naval gunners have mistakenly shot down Liberators, Mitchells, and Lightnings that failed to show IFF. In the Mediterranean theatre, our antiaircraft gunners have shot down troop laden airplanes through some IFF failure. We also have reports of U. S. Destroyers attacking our own PT's, and PT second friendly response! Figure 2-6 will show you what happened.

When you stopped your radar antenna on the enemy ship 8,000 yards away, you got an echo on your scope at 8,000 yards. You also received an IFF response from the friendly ship 8,000 yards away, which led you to think that the enemy ship was friendly. Of course, when you pointed the radar antenna at the friendly ship you saw its echo at 8,000 yards on the "A" scope, with the same IFF response at 8,000 yards. Remember that this

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condition can exist, and avoid being too quick to report two friendly contacts when it arises.

Should you have a friendly and an enemy ship at the same range when using the non-directional interrogator antenna, several checks on the position of the IFF signal in relation to the target pips will reveal which is friendly and which is enemy. *The IFF response will always appear immediately to the right of the target pip.* Since the possibility of a friendly and enemy ship maintaining the same range relationship to you over a period of time is quite unlikely, the pip which becomes separated from the IFF signal is the enemy ship. If there is no BN connected with your surface-search radar, you must depend upon your air-search radar and its associated IFF system to challenge the surface contacts.

Wide beam of BL and faulty identification.

Though designed as a directional antenna, the directivity of the BL array is limited, and it is to some extent subject to the limitations of non-directional interrogators. It follows, then, that identify positively two air contracts at identical ranges may result, for *it is not unusual to observe IFF responses for a full 360 degrees*, especially at short ranges. The limited directional characteristics are such that replies should be expected throughout a wide variation in bearing, especially below 12 miles range in the case of surface targets and below 50 miles range in the case of air targets.

Consider another confusing situation: assume that you have picked up a surface contact at 35,000 yards, and wish to challenge it with your IFF. If you have no 13L or BN connected with the surface-search radar, you must depend on the IFF equipment connected to the air-search set to do the challenging. The IFF band of frequencies lies just below that band used for our air-search sets, so you may expect the radiation characteristics of IFF radar to be very similar to those of the air-search sets. This means that radiation from IFF radar will not lie close to the surface of the water. Therefore, when you challenge the contact at 35,000 yards, it is very probable that no friendly indication will appear on your radar at that range even if the contact is friendly. The contact is unidentified until it closes to a range at which

some of the problems encountered with the non-directional system may also be a source of confusion when using air-search radar with the directional interrogator. Inability to enough of your BL energy reaches the ABK to trigger it. That range may be as

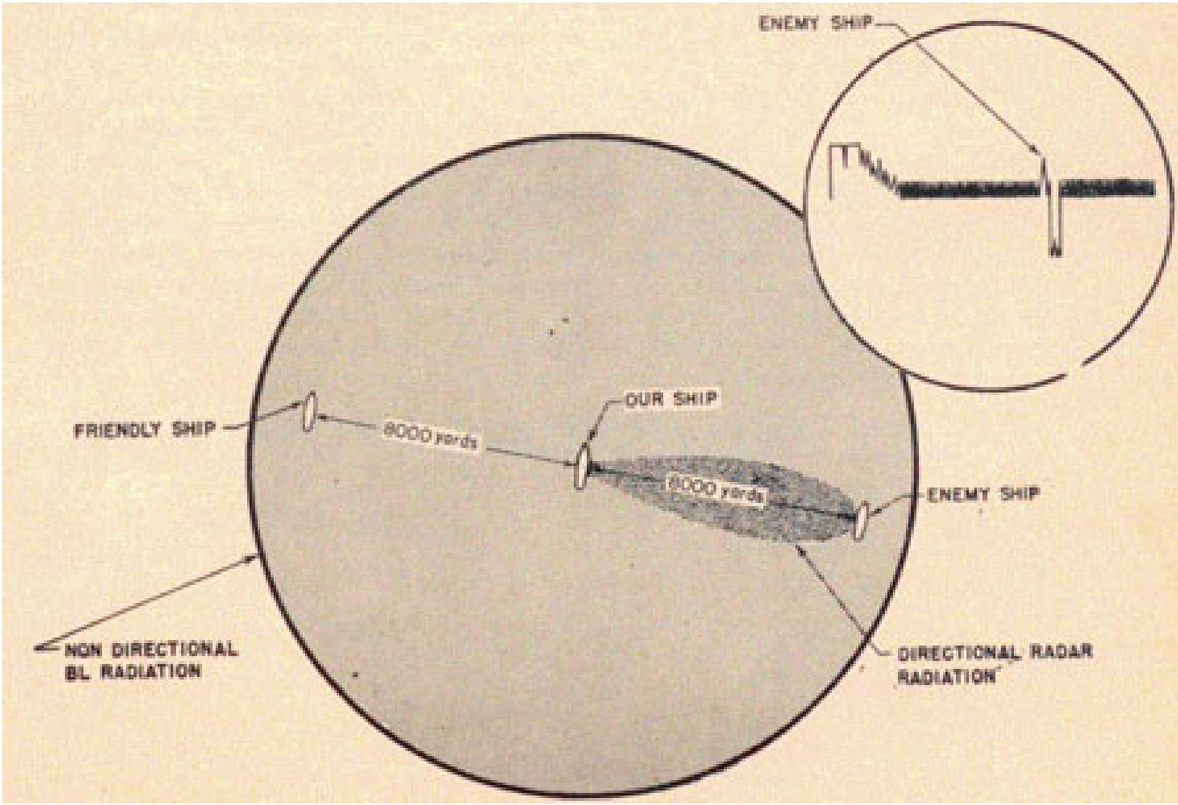

Figure 2-6.

short as 10,000 yards depending on the following factors: (1) height of the transpondor antenna above the surface of the sea, (2) materiel condition of both transpondor and interrogator, and (3) radiation pattern of the interrogator antenna in the vertical and horizontal planes.

As was pointed out earlier, however, you may get IFF responses from airplanes at greater ranges than you can see the actual echo from the plane for two reasons: first, the IFF radiation is directed upward from the water, just as air-search radar radiation is, and second, the power *originates* in an ABK, while power is only "reflected back" to our search radar after the search pulse hits an object. Inasmuch as the power transmitted by an major lobe of radiated energy has sufficient power to activate the transpondor. This can be done by turning down the plate voltage of the BL until you get an IFF signal only from the direction of the contact. As soon as you have finished the interrogation, turn up the voltage to its original setting.

Red and green band triggering.

For some reason, the Mark III IFF system was designed to operate in a band of frequencies that slightly overlaps the lower end of the air-search radar frequency band. This is illustrated in figure 2-7. The result is that a radar operator is placed in a difficult situation under certain conditions. With an

ABK is greater than that reflected from the plane carrying the ABK, it is possible for the coded IFF response to appear below the trace even though the search radar has not yet indicated the presence of a target.

"A sense of false security must not be permitted because many friendly blips from a group of planes can be seen on the radar screen. Enemy planes may trait such a group and attempt to take advantage of their transpondors to press home an attack. It is also possible for blips from friendly aircraft to conceal enemy surface craft."

360 degree IFF resulting from back and minor lobes.

Because of the wide horizontal beam, back radiation, and prominent side lobes of the BL antennas, you will find that a contact at short range can be interrogated almost continuously as the antenna rotates through 3600. Under these conditions interrogation is non-directional and subject to the same limitations described under non-directional IFF. It is often possible to reduce the power of the interrogator until only, the air-search radar set tuned to any frequency within the red band, it is often possible for the radar itself to trigger the ABK every time the antenna points in the direction of the transpondor. The result is an IFF indication flashing above the trace on the "A" scope continuously, even though the BL is turned off. When the ABK is out of adjustment, it may overlap into the green band of frequencies as well (indicated by the dotted line on the graph), affecting green band radars as well as those in the red band. Moreover, if you challenge the target with your BL you can expect to receive the usual Mark III indication below the trace, but not necessarily at the same time as the upward deflection. That gives three separate indications on the scope: the regular echo, the upward IFF signal, and the downward IFF signal. The latter two may or may not appear at the same time, depending on the relative frequencies of the search radar and the BL radar, which determine, of course, the time that the ABK will respond to each set. The situation is serious when a number of friendly and enemy planes are flying fairly close together, since the "A" scope becomes a mass of bobbing echoes and downward IFF signals that have no apparent relationship to each other.

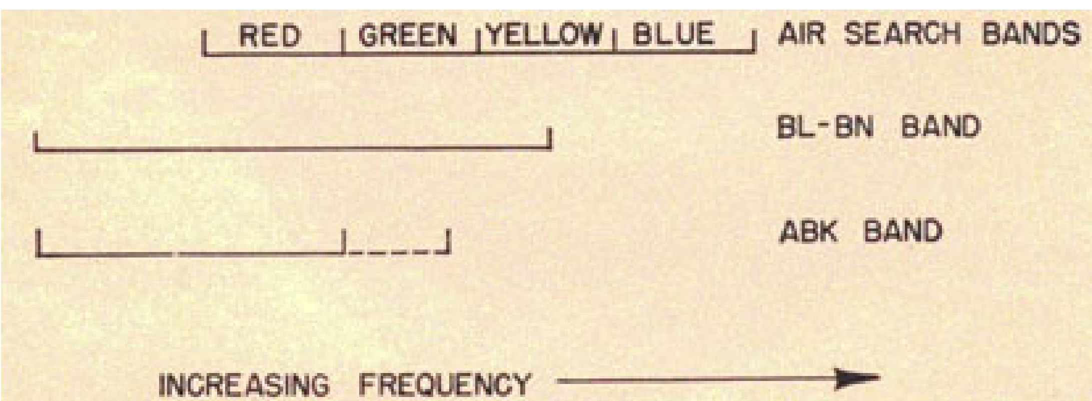

Figure 2-7.

GENERAL IFF PRINCIPLES

We have had an increasing number of reports from the Pacific Area stating that a response resembling the indications given by the obsolete Mark II IFF has been received. Authorities believe the Japanese are using the compromised ABE, since it

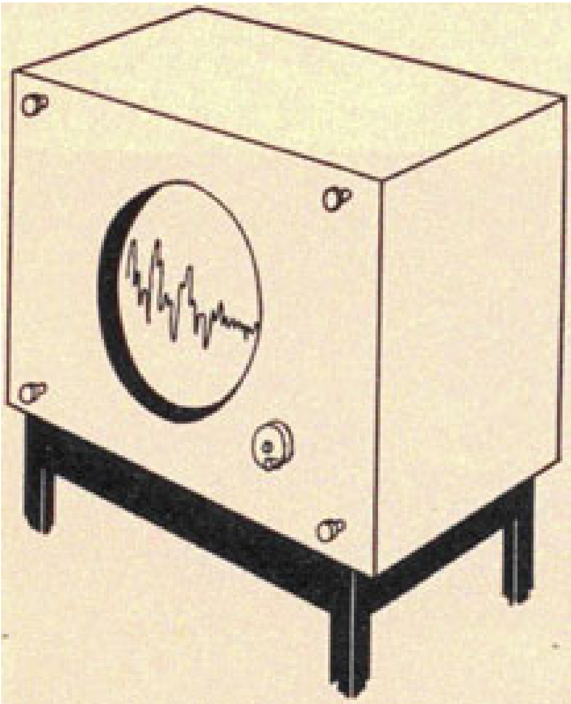

Figure 2-8. IFF interference.

puts the IFF response above the trace line. Hence the "positive" (above the time base) signals are to be regarded as no identification whatever-not as foe identification. IFF signals *below* the line identify "friendlies" whether or not accompanied by IFF above the line.

IFF interference and code readability.

Since the ABK is able to receive challenges from any and all directions, there may be several dozen interrogators challenging at once. Yet the ABK is equal to this situation, for it can answer up to 30 different challengers at one time without interference. Special provisions have been made to prevent ABK's operating near each other from triggering one another should their frequencies coincide.

are received *when challenging several planes in a group* or a large formation of planes, all with their ABK's on. The whole scope will appear as a flashing, confusing muddle, making it impossible to distinguish the signal of any one of the planes or to make out the code. Actually, codes are almost meaningless because each answering ABK will respond at a slightly different time and all codes will overlap. Under these circumstances the radar operator can at least recognize that responses consist of all narrow poises, a combination of narrow and wide, or emergency signals.

IFF signals too narrow on long range.

Selection of proper range scales during interrogation is another problem. It is exceedingly difficult to distinguish the IFF signals when the long-range scale is being used. The narrow IFF indications especially, are so compressed on the long range scale that it is next to impossible to tell an IFF indication from BL Pulse interference. Due to the thinness of the IFF signals on this scale, considerable difficulty may be encountered in reading the codes, provided, of course, that it is possible to distinguish the IFF from the flashing interference. It is wise whenever possible to use the mid-range scale or the short range for identification of contacts. Either of these scales gives better definition to the IFF signals; hence, identification is more reliable and less difficult.

SUMMARY

It is necessary to be especially alert when challenging a target, in order to recognize any or all of the confusing situations discussed in this section. In spite of the limitations of IFF radar, however, it is our only system for long-range identification of radar contacts. Combining a realization of its limitations with an up-to-the-minute understanding of the tactical situation will support the system so that satisfactory results may be obtained.

On the other hand, imagine how many IFF signals

In the future, IFF will continue to serve our forces afloat and airborne, with increasing reliability, and in valuable capacities not hinted at in this manual. Thorough understanding of this phase of radar, and intelligent, alert interpretation of IFF may well be responsible for saving a ship or winning an important battle.

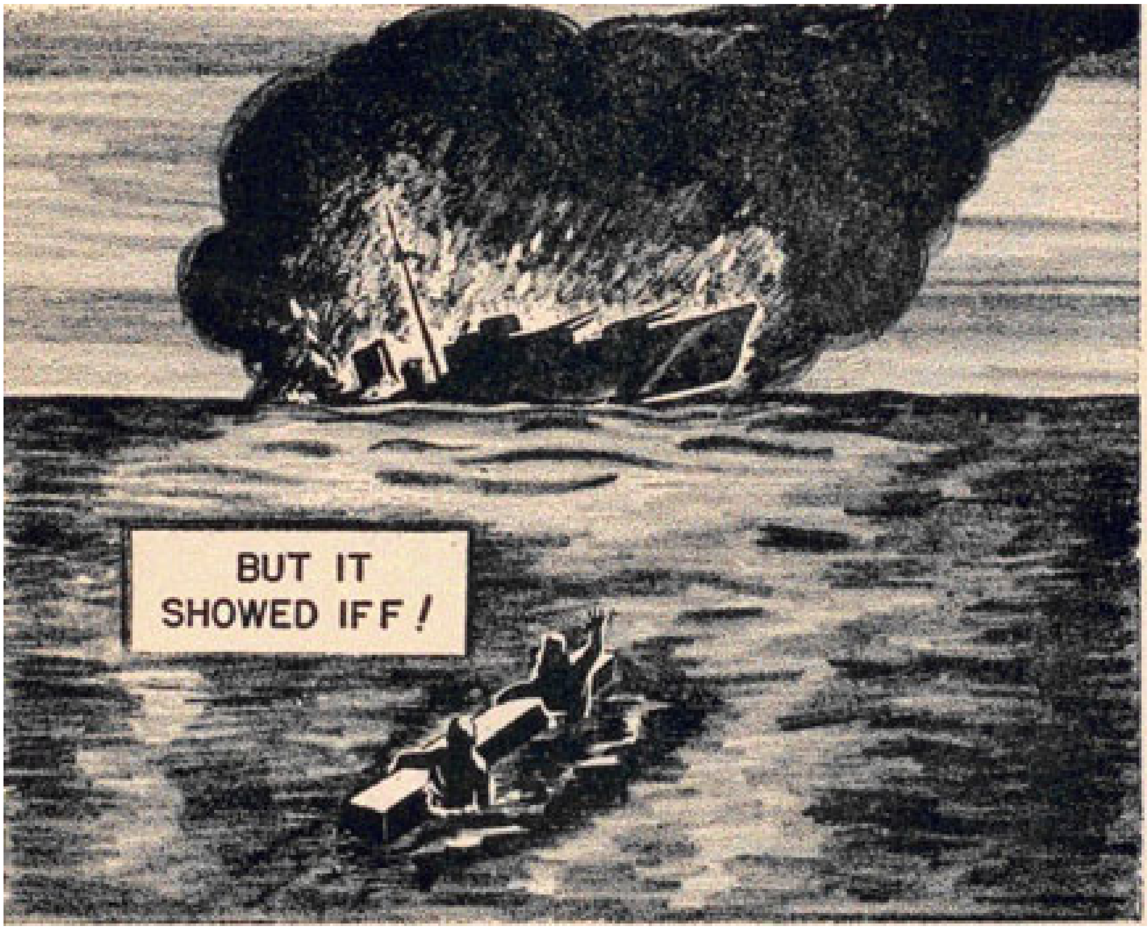

Figure 2-9.

[Previous Part] [Radar Home Page] [Next Part]

Version 1.00, 4 Sep 05

PART 3

OPERATION OF MAJOR TYPES OF RADAR

PART 3

OPERATION OF MAJOR TYPES OF RADAR

DEFENSE AGAINST JAMMING AND DECEPTION

OPERATION OF MAJOR TYPES OF RADAR

INTRODUCTION

Various radars differ in physical appearance. Each has its special knobs, types of presentation, and "gadgets," depending on the primary function of the individual set. Regardless of this physical variance, there is much that can be said, in a general sense, about good operational techniques for all radar sets. It is not intended, however, that the information in this section be followed to the letter under all conditions and in all tactical situations.

In order to gain the maximum tactical advantage from radar at all times, the radar operational techniques must change as the situation changes. Methods of operation must be flexible. Commonsense, and a thorough knowledge of naval tactics must determine which of these techniques should be used in any given situation.

A brief outline of the various basic controls and indicators will form a foundation for a more detailed discussion of operational techniques.

1. *Range scale*. What scale should be used tinder what conditions? How often should scales be shifted?

2. *Gain Control*. This corresponds to the volume control of a broadcast receiver. Should it be set high, low, or medium?

3. *Antenna rotation*. Should the antenna be rotated continuously? How fast should it turn? Should it always search an area of 360 degrees? If stopped, for how long?

4. *Range*. How should ranges be read? Should the range step and associated dials be used when provided? Should estimated ranges be used with the assistance of improvised scales?

determined by radar operating experience and common sense.

There are three basic types of radar:

1. Surface search
2. Air search
3. Fire control

In this section, the operation of the first two types will be discussed in general terms. However, since fire-control radars have such widely varying characteristics, recommended operational techniques will be particularized for each type, and will appear only in Part 4.

Each type of radar has been designed for one specific purpose, and there is nothing that you, as an operator, can do to modify these purposes. An air-search radar is a poor surface-search radar, and vice versa. Each of these types may serve in an emergency as a fire-control radar, but they cannot he expected to furnish ranges, bearings, and position angles with the same degree of accuracy as a fire-control radar specifically designed for that purpose. In case of failure of either the air- or surface-search radars, the fire-control gear may act as a search set.

SURFACE-SEARCH RADAR

The words *surface search* are misleading, since search is only one of many functions that has been delegated to this general type of radar. The six major functions are listed below, together with suggestions for optimum radar efficiency under each condition.

Long-range search for large targets.

It is essential that large surface targets be detected at the maximum possible range of the radar, so that effective attack or evasive tactics can be employed. The range scale used should be longer than the

5. *Bearings*. What are the different ways bearings can be read? Should the bug be used, or should a cursor be used instead?

6. *Scope*. If the radar set is equipped with two or more types of cathode-ray indicators, which should be used, and under what conditions is one preferable to another?

The answers to these questions, for different types of radar sets operating in various tactical situations, will provide you with the foundation of operational techniques. From this foundation, each special circumstance will require variations which can only be

expected maximum range on ships. The gain control should be set for maximum readability of an echo at 30,000 to 60,000 yards. This setting must be previously established for each particular radar set. The antenna should be rotated at the slowest available speed; an occasional sweep should be made using the manual control, if one is provided. The "A" scope (if the radar is so equipped) will usually show the initial contact before it appears on the PPI.

If a contact is established, stop the antenna (when means are provided for stopping it on contact) only long enough to obtain an initial bearing and the "A" scope range. Attempt to classify the contact specifically by utilizing previous knowledge of the capabilities of your particular radar. Data concerning previously observed maximum ranges on different types of ships, size of pip, and composition of pips will be useful in making this decision. Two courses of action are now open to you. You may follow the procedure outlined for auxiliary fire-control, or you may resume normal search. Your decision will naturally be based on the tactical situation.

Assume for this discussion that you are not interested in firing on the new contact. However, you might desire to keep a rough track thereof in order to maneuver around it. Your procedure, then, would be to continue a long-range search, reading bearings and ranges of the contact "on the fly," without stopping the antenna. With practice, sufficiently accurate data may thus be obtained to and easier to obtain if the "A" range scope is equipped with a scotch-tape range scale, and if the PPI is marked with thinly inked range circles. Bearings can be estimated directly from the PPI.

Short-range search for small targets.

This might be called the submarine or PT boat search, and should be conducted primarily when cruising independently. When cruising in company, the OTC will normally assign the search function of each radar in the force. The range scale used for small target search should usually be the shortest available scale, although on some sets it may be found that the mid-range scale can be used to better advantage. The receiver gain should be *varied during the entire search* , its setting depending on the amount of sea return present and other tactical considerations. Look for periscopes close aboard, increase the gain a little, and search near the outer limits of the sea-return area for surfaced submarines and small patrol craft. Remember that *sea return is basically the same as an echo from a target, and*

maintain a reasonably exact track. The important consideration of the on-the-fly operating technique is that you are continuing to search for other contacts (which the Captain may later decide to attack) without sacrificing the search efficiency of the radar by stopping its antenna on a contact that admittedly is not of primary interest.

Ranges read on-the-fly will be more nearly accurate

that it must be present if a small target echo is to be detected.

Operating experience will determine the correct gain setting for different amounts of sea return. Antenna rotation should be as slow as possible; again, make occasional manual searches. New targets should appear on either the "A" scope or the PPI almost

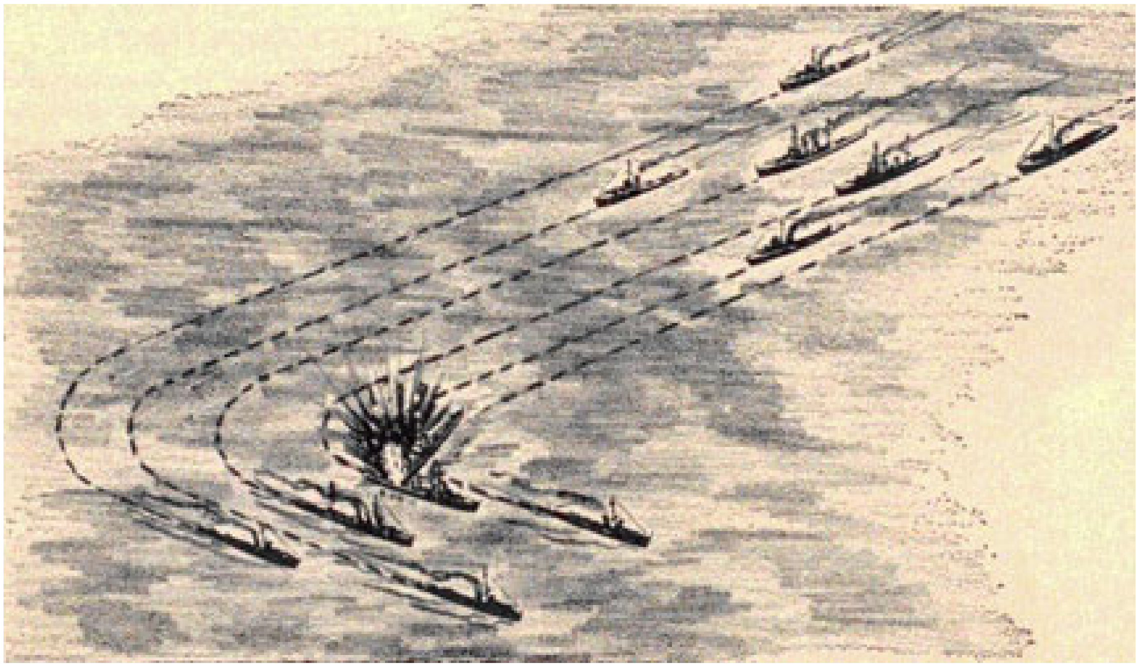

Figure 3-1. Avoid this by using radar when changing course or leaving a formation.

simultaneously, provided the gain is set high enough for PPI operation. These indicators should be alternately observed for equal periods of time to reduce eye strain and monotony. If a contact is made, follow the procedures listed for long-range search. If an attack is to be made on the targets, coach the fire-control radar on to the contact and resume the search immediately. There is no need to attempt to duplicate the function of the fire-control radar with the search radar, unless the search radar is required to solve a torpedo problem while the main battery fire-control radar is busy.

directly upward from the water's edge, you are safe in assuming that the range to the nearest land is positively indicated by the range obtained from the radar screen. If, however, the terrain rises gradually from a waters edge to a mountain or range some distance inland, the possibility exists that the pip on your radar screen has been produced by reflection from the mountain range, and not from the beach. It is almost impossible to determine the exact point of reflection from a sloping surface, and an error of only a few hundred yards might prove disastrous in close navigational work. Always keep a contour map of nearby land available for reference when

Station keeping.

There are some situations that will demand the exclusive use of a search radar set for station keeping. It must be understood that when this radar is used for station keeping, it is not performing its intended purpose as a search radar.

The normal requirements of station keeping are such that the antenna should be rotated continuously, using the short range scale on the indicator. Bearings and ranges on the guide, or on other suitable ships in the formation, may be estimated from the PPI scope. It has been found useful, when proper conditions prevail, to maintain a plot directly on the face of a remote PPI scope with a chinagraph pencil, or to put a spot on the master PPI representing the place on the scope where the guide should appear when you are on station. Any indication of incorrect station will become immediately evident in this system. Search should not be forgotten when keeping station, and a regular plan of shifting range scales and receiver gain should be adopted. *The gain should be turned down only while obtaining necessary station keeping information*.

Admittedly, there are situations that demand extremely accurate station keeping. When such is the case, auxiliary fire-control procedure should be followed, utilizing the most accurate ranges and bearings available from the radar. Search must necessarily be forgotten, or minimized, during intricate maneuvers.

Navigation.

One of the most useful functions of a surface-search radar is its contribution to navigation. However, the limitations involved when radar is put to such use must be thoroughly understood. Unless you know the contour and composition of the land that is reflecting the radar energy you are navigational information is required. After careful practice in "radar map" comparison with contour maps of familiar land, you may become proficient in estimating reflecting surfaces on unfamiliar terrain. This discussion applies, of course, to piloting, since radar "cutons" will usually differ from visual tangents, depending again on the contour of the land.

The beam width of the antenna must also be considered when an attempt is made to obtain a radar picture of a shore line. A few illustrations will show why this is so.

The first series of illustrations in figure 3-2, show how the radar shore line changes as the ship moves from one position to another. Notice that the harbor has been completely obscured by the radar shore line in all instances, and that a ship that might be situated anywhere inside the shaded areas would not appear on account of this beam-width distortion. The explanatory remarks in the first drawing are applicable to all of the subsequent illustrations.

All of the examples have been based upon the assumption that equal reflection is obtained from all points along the shore line. While this is rarely the actual case, it is a necessary assumption for a theoretical situation. The radar shore line will differ from the actual shore line by an amount depending upon the beam width of the antenna, the contour and composition of the land in the immediate vicinity of the shore line, the bearing of the ship from the shore at any given time, and the amount of receiver gain used.

It is impossible to describe all situations that might he encountered in ranging upon a shore line with radar. Each problem has its own special features, and must be treated individually by the ship involved.

More accurate fixes can be obtained if echoes from

never safe in reporting a range to the "nearest point of land." For instance, if you are ranging on a sharp cliff that rises

smaller land masses are used. On the PPI shown in figure 3-3, points X and Y would provide the best navigational fix.

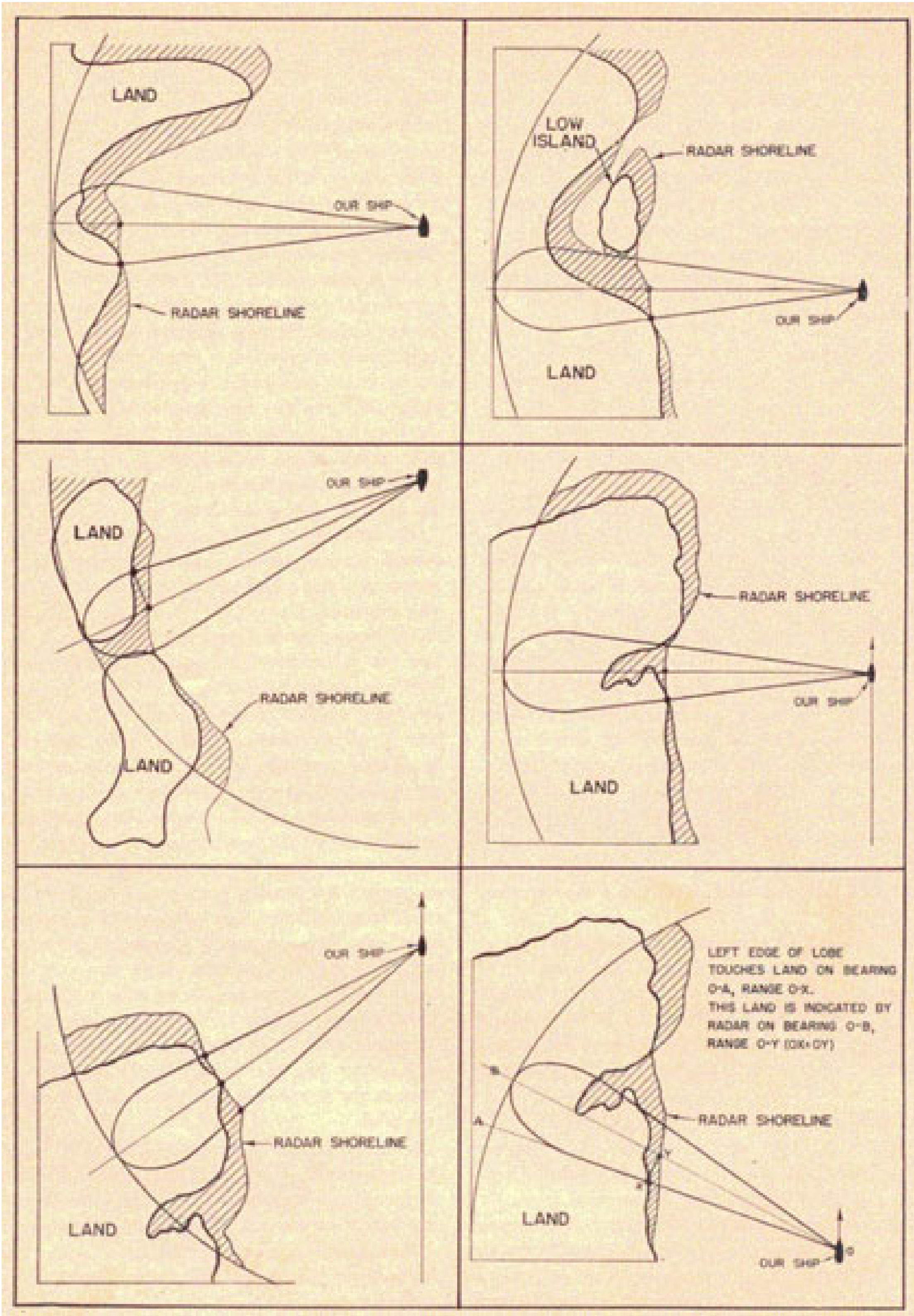

Figure 3-2.

3-6

OPERATION OF MAJOR TYPES OF RADAR

It is often helpful to plot the range and hearing backward from your estimated, or DR position, and analyze the chart to determine if there is a possible reflecting surface. Good and had ranges may he identified in this manner. It should he remembered,

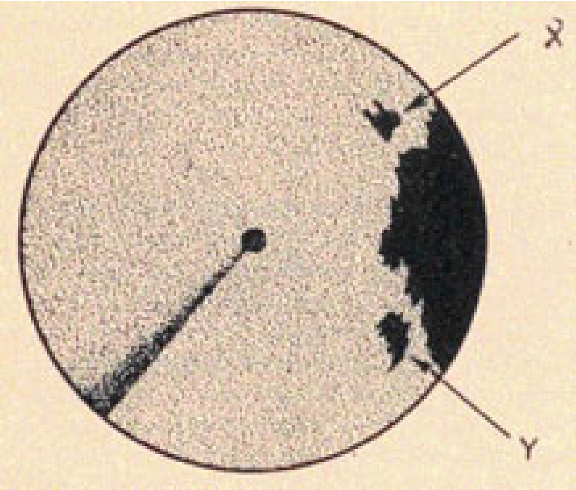

Figure 3-3. Small land masses provide accurate navigational fixes.

however, that the chart itself may he in error, so its known accuracy must be considered in this procedure. A collection of sketches of the composition of pips may be useful when you return to a particular location.

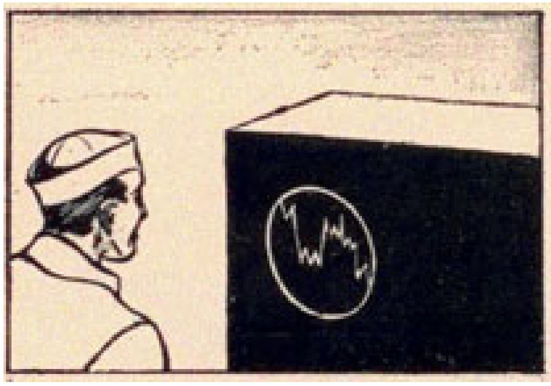

Figure 3-4. Prominent landmark pips help in locating ship's position.

radar, or if such equipment has failed, you may have to depend completely on surface-search radar for the control of gunfire.

The radar operator must furnish more accurate ranges and bearings than those provided by obtaining them "on the fly." There are two methods of developing a plot for fire-control work. These will be explained in detail in RADFIVE. Regardless of which method has been selected, you must stop the antenna to obtain accurate ranges from the "A" scope and bearings from the bearing indicator. If no "A" scope is available, the most accurate method of obtaining this data must be selected, depending upon the particular radars installed.

For radar spotting, the antenna must be fixed on the target while the shells are in flight so that splashes may he noted on the radar indicator. The torpedo-control work is usually delegated to surface-search radars and CIC, since the fire-control radar is busy furnishing necessary information for the solution of the gunfire problem. In spite of the high degree of accuracy necessary to the satisfactory solution of fire-control and torpedo-control problems, the best procedure is to make one or two complete antenna rotations every minute or so to make sure that bigger game is not approaching from a different bearing.

Composition.

Continuous practice is needed by all radar personnel before they become proficient in analyzing the pip on a radar screen. Every opportunity should be utilized when in company with friendly ships to make notes (on effects of position angle, size and type of targets, ranges, and relative bearings) on the composition of an echo.

Auxiliary fire control.

You are, by definition, using your surface-search radar as a lire-control radar as soon as you start to track a contact. This is often a desirable procedure in spite of the fact that the search efficiency is decreased during such operations. If your ship has no fire-control

Familiar double-peaked echoes are often noted from large ships, such as battleships and carriers, at medium or close ranges. Fluctuations of the pip are different when the reflecting object is a rolling destroyer or a more stable cargo vessel. These are among the "tricks if the trade" that must be mastered by an operator before he can he considered above average.

AIR-SEARCH RADAR

The continually changing tactics of the enemy relating to air attacks makes it difficult to outline the best operating techniques for this type of radar. Although the basic tactical situations will be discussed in this section, it would he well to remember that there are no set operating conditions that will hold true for all conditions of radar protection and offensive action.

Long-range, early warning air search.

The problem involved in this type of search is obvious. We want to make initial radar contact with the enemy attack groups at the maximum radar range. Patrol planes and snoopers most be intercepted before they can radio contact reports about our task force.

The range scale should he set to provide the longest available range in accordance with the observed maximum ranges of the particular radar, The PPI and the "A" scopes should be watched alternately, with the antenna rotating slowly. Receiver gain should he set for maximum readability of the indicator under observation. This means that the gain control will be at a different position for "A" and PPI operation.

thorough search of the 360 degrees area around the force. *Keep the antenna rotating slowly*.

Bearings should be obtained from the bearing cursor on the PPI, and ranges should be estimated directly from the PPI without using the range mark. This will be facilitated by inking range circles at five-mile intervals on the glass surface of the PPI tube, eliminating the use of the unsatisfactory range scale provided with these units. When the PPI is not available, ranges and bearings must be read "on the fly" with the aid of a scotch-tape range scale on the "A" scope.

Short-range search and multiple target tracking.

This search procedure could be followed when a torpedo plane attack is imminent or probable, and when raids are approaching from different bearings.

Upon radar contact, the antenna should be stopped, and the echo scrutinized to determine the composition of the pip. The target should be challenged with the BL, and the "A" scope should show the IFF response if the target is friendly.

The slow antenna rotation should be resumed immediately, and the all-around search continued to detect other possible targets. The procedure to follow at this time will vary, depending on many factors too numerous to present in this book. The type of force, the availability of fighters, and the discovery of other bogies will influence the decision of the task force commander, but this much can he said for the general case: the discovery of a bogie demands an even more

Continuous antenna rotation is a necessity. The range scale should be set at its medium position, and the gain adjusted for maximum readability of the PPI. Ranges and bearings must be obtained in the same manner as that discussed for long-range search (from the PPI).

The speed of antenna rotation should be increased as the attack closes on the force, and you must be prepared to shift to the short-range scale as soon as the targets have reached the outer range limits of this scale. You must also be prepared to change to fire-control liaison operation since it is closely allied to short-range search operation.

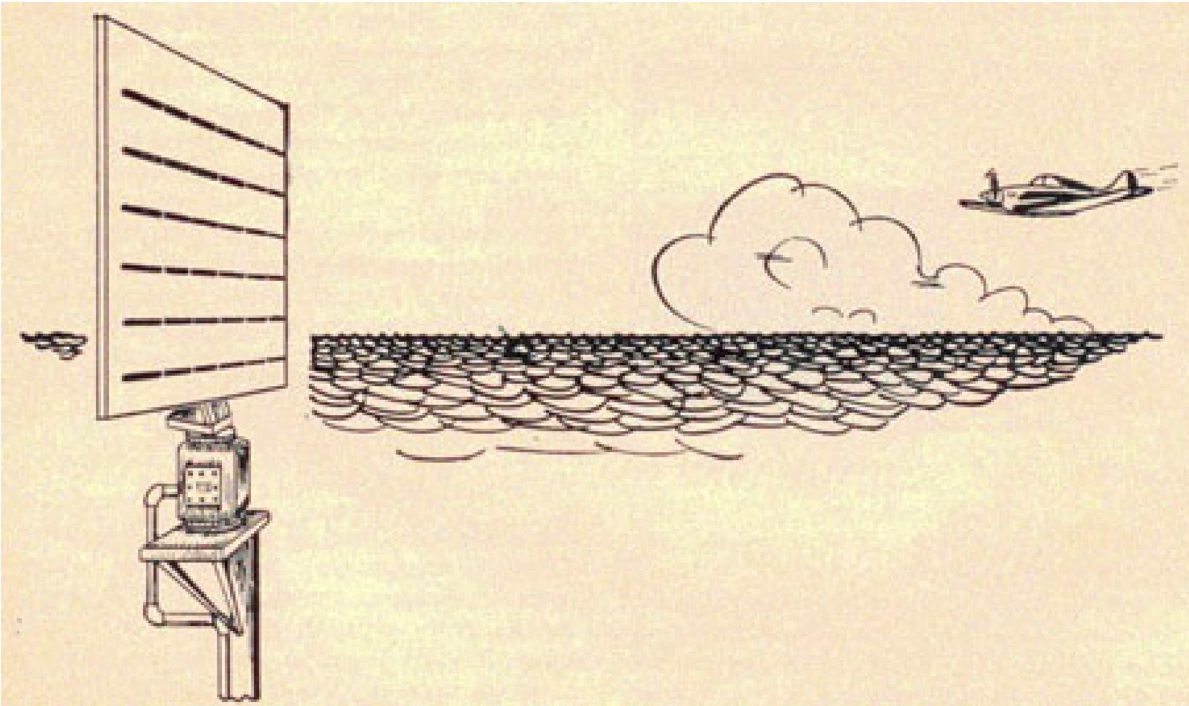

Figure 3-5. Long-range, early warning, air-search radar.

It is particularly important to maintain a plot of all friendly planes in the air when contact with the enemy is possible. Unless this is done, a "snooper" or low-flying attack plane may appear on the screen of the radar unknown to the operator. This practice may require that the antenna be periodically stopped to check the IFF return, but once a track has been started on any particular plane, the identification problem should be simplified, and bogies detected immediately.

Fighter director tracking.

For night interceptions this type of radar operation should be carried on during night fighter work so that the fighter director officer can effectively make a PPI interception. The 360 degrees search is abandoned, and the antenna is directed over only the area in the vicinity of the attempted interception. This method, however, concentrates all your efforts on a small area, and should be utilized only if there is sufficient air-search coverage from other radars in the force.

If the operator-plotter team is unable to provide an up-to-the-minute radar picture of daylight interception, fighter director tracking must be employed. Multiple-target tracking is preferable to this method, however, since all areas are covered by the radar.

Over land tracking and over land search.

Tracking targets over land is not as difficult as it may seem at first, although it is an art which requires considerable practice. Actually it is a special type of fighter director tricking requiring its own special technique.

Whenever planes fly over land masses, their contacts can not be seen on the PPI. Use the "A" scope and the shortest range scale on which the plane can be seen (if you intend to track it). With the antenna in manual rotation, train slowly through the land mass, watching for a bouncing pip among the steady ones. This will indicate the presence of a plane over land, and you may then read its range almost as accurately as if land were not there. To find its bearing, adjust the antenna carefully for maximum activity of the bouncing pip.

You should practice this technique on friendly planes when in port. IFF affords an excellent method of checking from time to time to be sure that you are on the plane.

Fire-control liaison.

When attacking groups of planes have closed within 20 miles of the force, it is essential that close cooperation be maintained between the air-search radar and the fire-control radars. The guns must often be "talked on" directly from the air-search radar, or by electrical target designation systems connected to that radar.

Depending on the particular installation, the radar may be set to furnish either true or relative bearings. It is preferable to utilize true bearings, provided suitable conversions have been incorporated in the

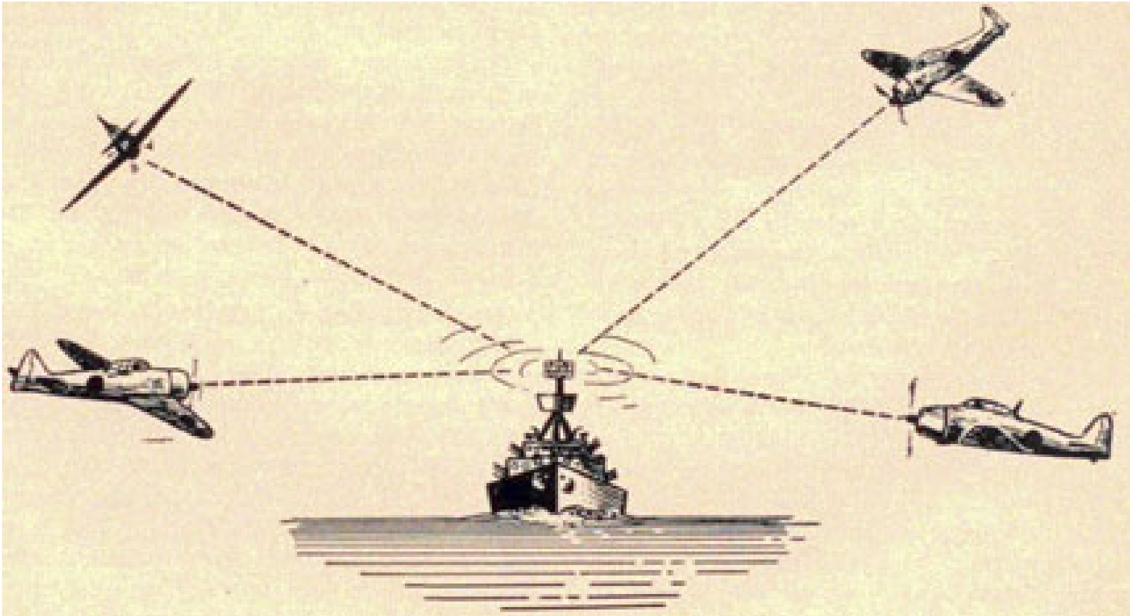

Figure 3-6. Speedy antenna rotation for short-range target tracking.

fire-control equipment. If not, relative bearings should he furnished.

The antenna should be rotated as fast as possible, and the range scales used should be the shortest available on the radar. While this measurably decreases the air-search efficiency of the ship, primary consideration should be given to gunnery when planes have closed to attacking ranges.

Side lobes are especially troublesome in this type of operation, and the operator must be quick to distinguish the extraneous echoes involved. It will help to reduce the gain as far as practicable, in order to minimize these echoes. They may often be distinguished by comparing their width (in degrees) with the echo received due to the main-lobe radiation.

Composition.

The "A" scope is of the greatest value when the composition of a contact is to be obtained. Constant drill by operating crews in estimating the composition of friendly planes is of inestimable value as a means of obtaining reliable data to be used on enemy raids.

Composition of raids should be checked at regular intervals, about every 20 miles of target travel, to make sure that any splitting of attack groups may be noted: the estimated size of the raid should be rechecked.

PIPOLOGY

INTRODUCTION

Pipology involves the study and interpretation of all types of contacts seen on radar indicators.

Composition is a closely related word, but not so all-inclusive, and answers the questions: what type? how many? friend or foe? Determination of composition is an art, and is perhaps the most enjoyable phase of radar operation. Given enough time, almost anyone can get the bearing and range of the target, but it takes skill, imagination, and above all, experience to determine composition. With continued experience and increased skill your predictions should be about 80% correct. Trying to identify every echo that appears will give you the practice you need, and whenever possible, get someone to find out what the target is, or was, and thus check the accuracy of your estimate.

Ability to interpret pips comes both from knowledge gained through study and from endless hours of practice on the radar. It is important not only to recognize the target, but also to recognize it in the shortest possible time. Some of the advantages of speed are:

1. It aids the plotters in assembling information.

2. It aids the ship's officers in making quick evaluations and decisions.

3. *It gives the gun-director crew and computer operators much needed time in laying guns on the target.*

4. It adds to the over-all efficiency of the radar watch.

Pips are of various types. Each type lends itself to

1. Size of pip.

2. Shape of pip.

3. Bobbing or fluctuating in height.

4. Movement in range or bearing.

The "A" scope is most satisfactory for observing size and *fluctuation* of pips, an expanded or short range "A" scope for observing *shape* , while *movement* is best seen on the PPI. The following section takes up these pip characteristics in some detail to aid you in interpreting the things you are likely to see on radar scopes.

COMPOSITION

Friend or foe.

The first thing to determine obviously is the friend or foe status of the contact. This can be done only by using your IFF interrogrator, or by securing the information from another ship in your force which has already established this status. The method of handling such a situation is a matter of doctrine. You will be informed as to whether or not you are to make the identification, generally you do.

Having established the friend or foe status of the contact, the next step is to notice the rapidity and the extent of the echo's fluctuation. Consider the height of the echo, remembering the effect of range and fades; then note the depth or thickness of the echo. If the echo is saturated, reduce the gain. Look at the top and sides of the echo for any indication of two bumps or many little humps. What is the speed at which the echo is moving? Look at everything and draw on your entire background of knowledge and experience to interpret what you see.

interpretation. In general there are four characteristics of pips which will give you information useful in interpretation.

PIPOLOGY

Estimating the size of ship targets.

First of all, upon what does the size of the pip (strength of received echo) depend? The answer is, unfortunately, quite a number of things, the most important of which are:

1. Range of the target.

2. Size of the target.

3. Height of your antenna (especially when surface targets are concerned).

4. Height of the target.

5. Whether the target is bow or broadside (target angle).

6. Atmospheric conditions.

7. Material composing the target.

8. Correctness of tuning.

9. Materiel condition of the radar set.

Due to the many variables involved, it is not possible to determine the exact size of the target in every case, but you can always make a reasonably will tell you is relative size of various targets at approximately the same range.

The best way of determining the approximate size of a target is to observe the range at which it was first detected. This method is especially good with micro-wave surface-search radars such as the SG, SF, SL, SO, etc. Radio waves from these radars travel in practically a straight line. At any given range it takes a certain size object to give back an echo that is just visible on the screen or scope with your radar tuned up as well as possible. Therefore, various types of targets or types of ships first become visible on the scope at some definite range. The echoes come from the ship's mast and upper superstructure first. The superstructure offers approximately the same size target regardless of the direction from which it is seen.

Each radar will have its own characteristic ranges for detecting the various types of targets, depending on how high the antenna is mounted, the power, and the sensitivity of the particular gear.

An estimate of the approximate size of targets at less than the maximum range can be made by considering the strength of the echo, the range, and the target angle. To facilitate this process a log should he kept for recording these data. The data can then be tabulated for quick reference, showing echo strength in E units, range, target angle, and type of -hip, as well as any special features of the pip that might be noticed.

The E system of designating echo strength is based on the ratio of the echo height to the grass height.

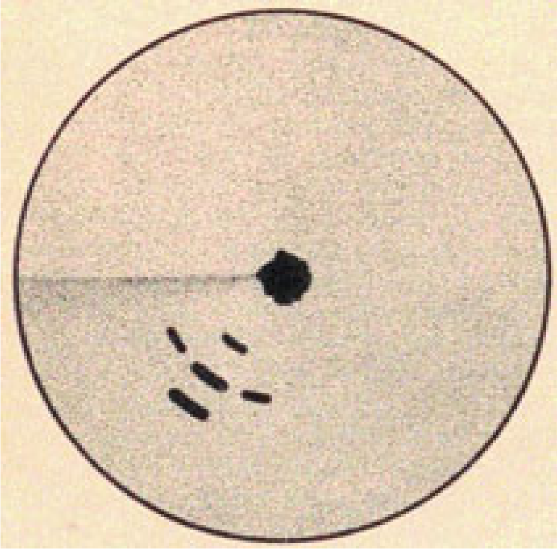

Figure 3-7. Two medium, three small targets.

accurate estimate. This much you do know: if you have a large and a small target at approximately the same range, the larger target will produce the large pip (stronger echo), other variables being equal. So, if you detect any enemy task force approaching, the picture on your PPI might appear as shown in figure 3-7. Thus, the only *positive* thing that size of pip

This ratio is not affected by the setting of the gain control. See figure 1-17 in Part 1, General Radar Principles.

Target angle is an important consideration except at extreme maximum range. It is the angle measured from the bow of the target ship, clockwise (to the right) to a line drawn between your ship and the target ship. In other words target angle is the relative bearing of your ship as seen from the target ship. If you are astern of him the target angle is 1800; if you are broad on his port beam, the target angle is 270 degrees. Target angle can be found by tracking the target a few minutes (see RADFIVE, *The Surface Plotting Manual*). Reference to this tabulation will

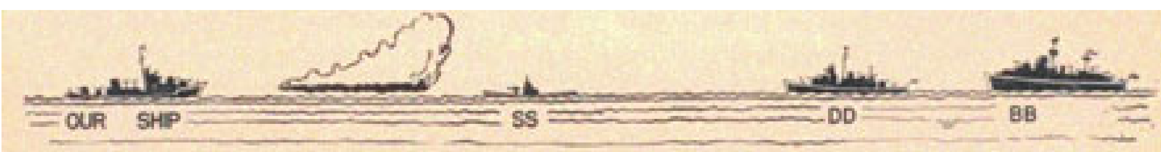

Figure 3-8. Relative maximum radar ranges for various types of ships.

provide one of the best clues to the approximate size of ships seen first at less than maximum range.

The bouncing motion of a pip provides another means of estimating the approximate size of a ship. A large target usually shows up as a slowly bobbing pip, varying in size from medium to large. A smaller object usually gives a more violently fluctuating pip, and, especially if the sea is choppy, may produce an echo that will flutter between a medium-sized pip and no pip at all. Of

while figure 3-10C shows the picture appearing on the PPI under the same conditions. Examine carefully the pip's size. Now carefully cheek the pip's size on figures 3-11B and 3-11C with the antenna trained on two targets within your beam, both at the same range.

On the range scope, the pip is much higher as a result of more reflected energy teaching your antenna, while on the PPI, the pip is much wider. The pip is not deeper (thicker), since the time base represents *only* the *range* of the target. Figures 3-

course, roughness of the sea affects the amount of fluttering of pips and this must always be taken into consideration. On a calm day echoes from stationary objects, such as a lighthouse, will produce an absolutely steady pip, hilt if your own ship is rolling, even this type of object will produce a rising and falling pip, unless the antenna is stabilized.

Another way of occasionally identifying the type of moving object is by tracking, and plotting its position over a period of time to determine its speed. Keep in mind, however, that the movement of your own ship makes the target change position on the radar screen.

Here are some examples of information which you might obtain from a radar. Try to determine from them what the target is: You detect an object at 9,000 yards. On the PPI it only shows up once every two or three revolutions. When examined on the range scope the pip is fluttering rapidly. From tracking and plotting the target, you determine its speed to he about 35 knots. Since you did not pick up the target until it was fairly close to you, this indicates that it is a small target: the rapid fluttering also indicates a small target. From the speed of 35 knots you can assume the target to be a small, fast, boat, probably a PT. The same type of target, had it been stationary, might have been a buoy, especially if you were near land where buoys might he expected.

Estimating the number of ships.

Bearing and range resolution. Targets at the same range will present separate pips only if they differ in bearing by a certain minimum angular distance. This angle is called the *bearing resolution* of the radar, and it varies from set to set (being proportional to beam width). On the other hand, targets on the same bearing will present separate pips only when they are separated in range by a

11B and 3-11C show only one pip, since the targets were too close together for the bearing resolution of the radar used.

Figures 3-12B and 3-12C are the pictures appearing on the range and PPI scope respectively, when the targets are still at the same range, but with their bearing difference great enough to obtain bearing resolution, as indicated in figure 3-12A. Here, a new pip will appear as the antenna is trained to the bearing of each individual target; their energy will not be cumulative since difference in bearing is greater than the antenna's *effective* beam width.

Next, consider figures 3-13B and 3-13C. Here again you see the antenna pointing on only one target, as noted in figure 3-13A. Compare these pips carefully with those appearing in figures 3-14B and 3-14C. Notice that the pips in figures 3-14B and 3-14C are *deeper* as a direct result of a *range difference* between the two targets. Should the two targets under observation have even a greater range difference, the deep pip will appear split, as shown in figures 3-15B and 3-15C. Here, the number of individual peaks will indicate the number of targets.

Effect of range on bearing resolution. As shown in figure 3-16, the ability of a radar to separate two targets close together in bearing improves as the range *decreases* , because the angular difference in their bearings is *increasing*. Notice that the two ships are covered simultaneously by the effective part of the lobe when at a range of 18 miles. On the other hand, when the same two ships close to five miles, the effective part of the beam cannot touch them at the same time, and they can be seen as two separate contacts. The bearing resolution angle, in other words, intercepts a smaller distance at short range than it does at long range. Keep counting contacts as the range closes.

Effect of sweep length on range resolution. Due to the fact that pictures are traced on scopes by a

certain minimum distance. This distance is called the *range resolution* of the radar, and it also varies from set to set (being proportional to pulse duration)

Figure 3-10B shows the picture appearing on the range scope with the antenna trained on a single target,

relatively large spot of light rather than by a tiny point of light, a certain amount of definition is lost. Regardless of the range scale in use, the size of the electron beam spot remains the same; consequently, it becomes increasingly difficult for this beam to trace a clear picture

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of the two contacts on the same bearing as they move closer to one another on the scope. Therefore, the longer the range scale, the closer the contacts will move to one another on the range axis and the more likely they will be to blend into a single contact. This effect is more noticeable on the PPI or "B" scope than on the "A" type.

The PPI drawings in figure 3-17 illustrate the point that a four-ship contact may look like one ship when

seen on the long-range scale, like two when seen on the medium-range scale, and like four on the short-range scale, due to improving resolution. Study composition on the shortest scale possible.

Effect of receiver gain on range resolution. The range resolution will always be best when the gain control is turned low enough to present saturation. You cannot read composition on a saturated echo (one so high on the range scope that the top is squared off),

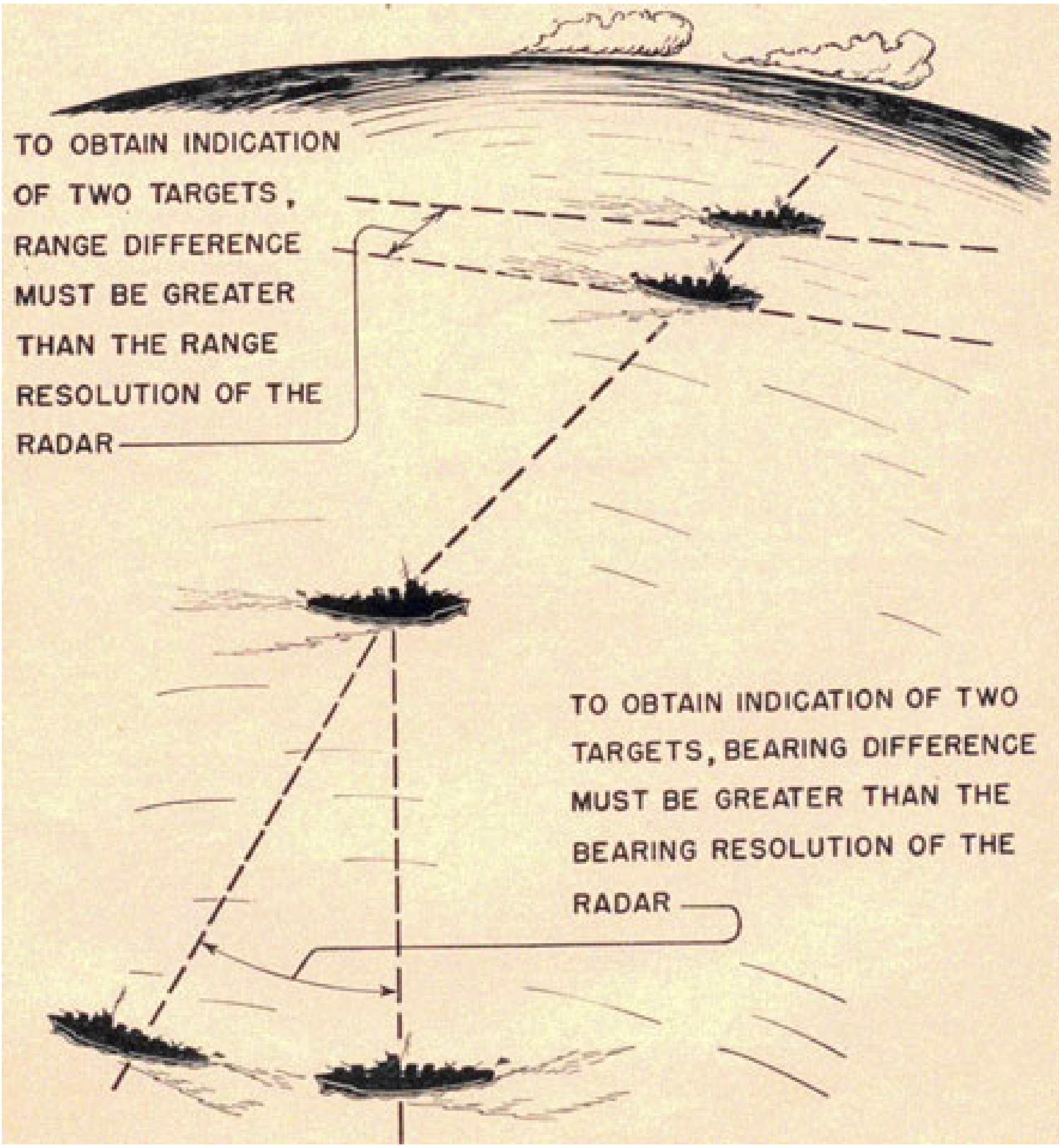

Figure 3-9. Bearing and range resolution.

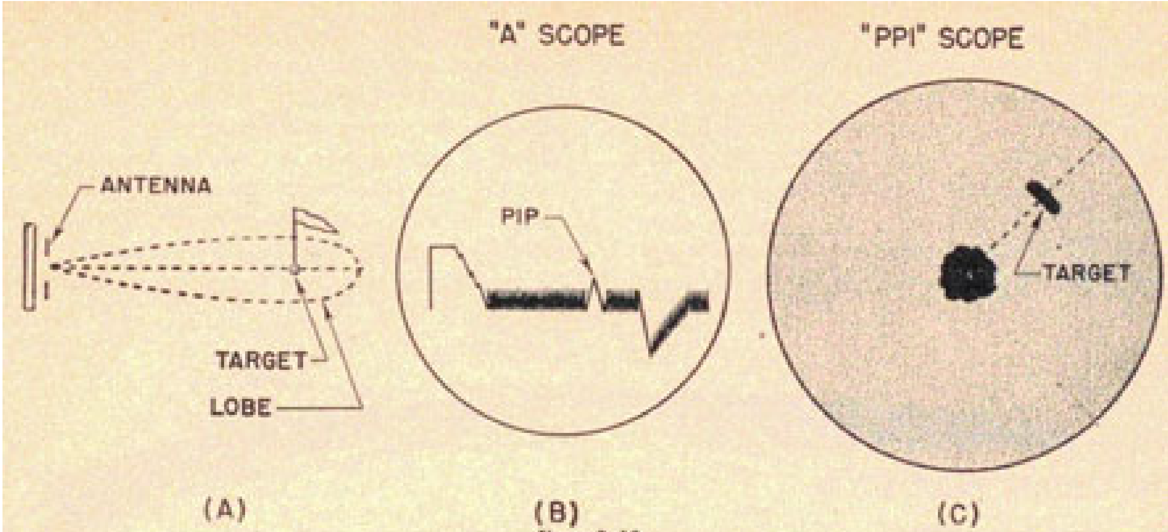

Figure 3-10.

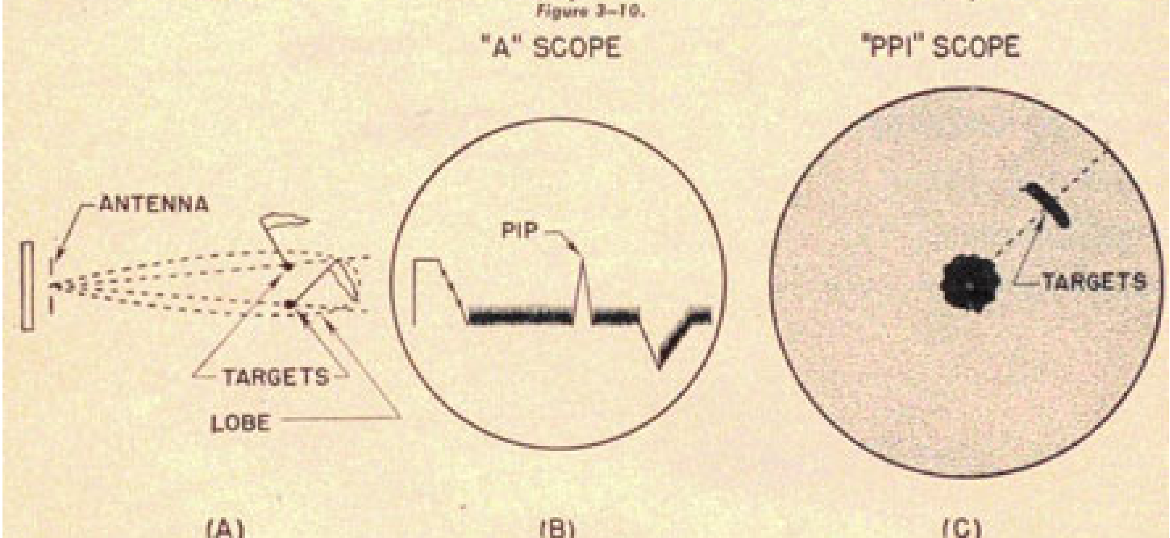

Figure 3-11.

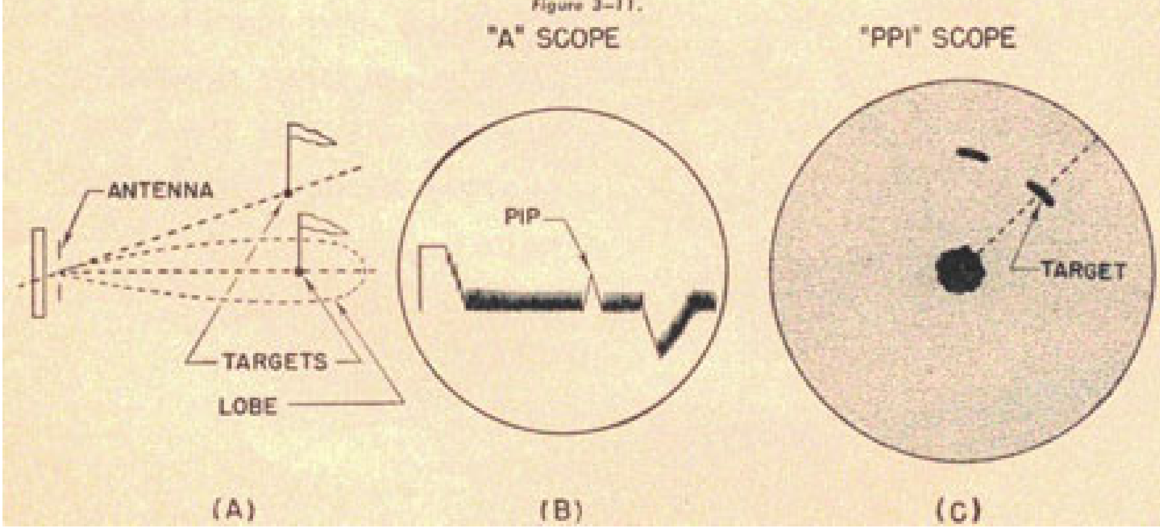

Figure 3-12.

PIPOLOGY

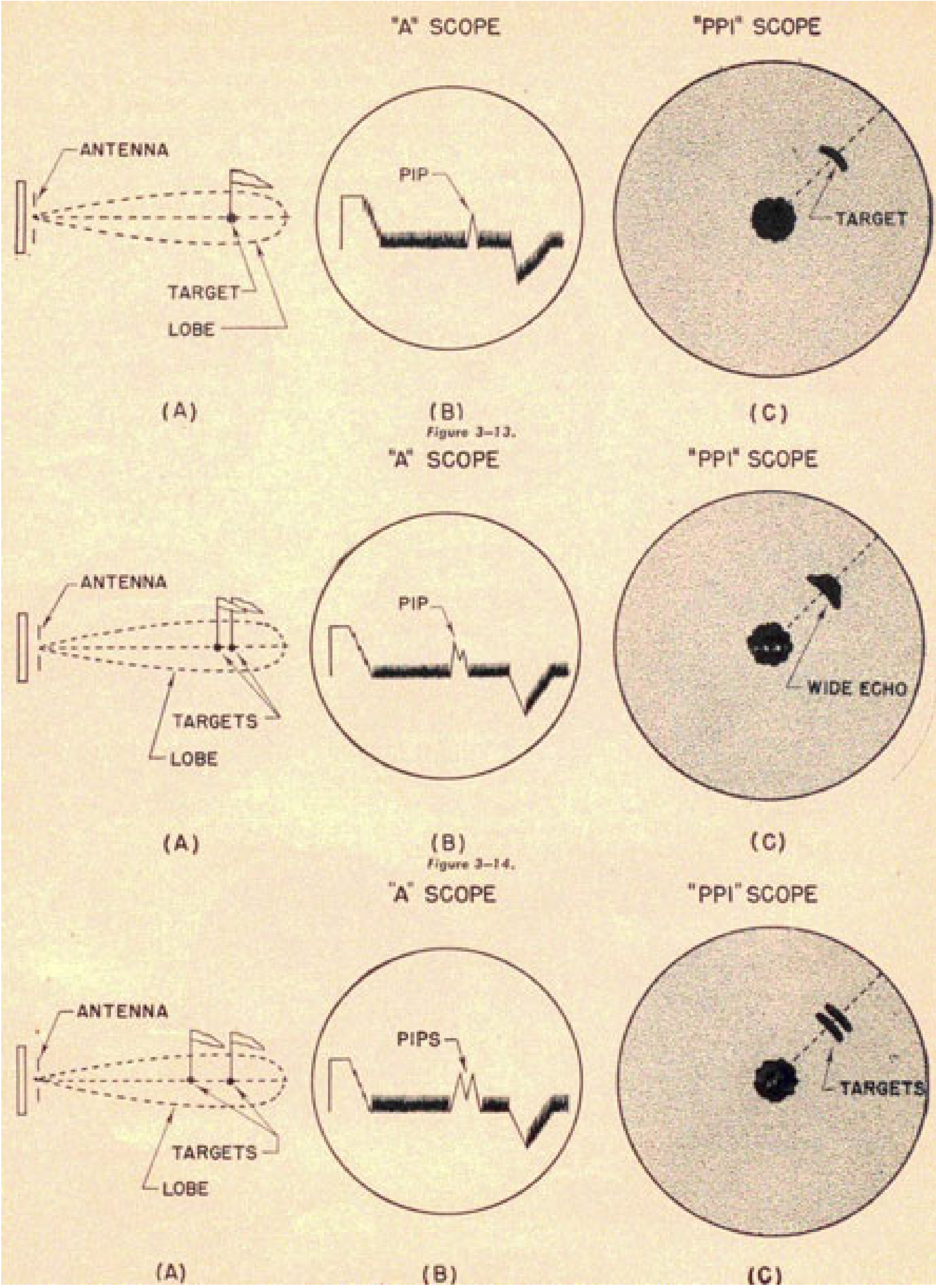

Figure 3-15.

RADAR OPERATOR'S MANUAL

so turn the gain down momentarily when necessary. Do not make the mistake of leaving it low, since this will decrease the sensitivity of the radar, (See fig. 3-18.)

To help you get a clearer concept of resolutions, let us consider the topic from another point of view, analyzing the effect of both bearing and range resolution at the same time rather than one at a time as previously done.

One-pip areas. The diagrams in figure 3-19 illustrate the fact that the bearing and range resolutions of the "A" scope are superior to those of a PPI on the same radar. Furthermore, they illustrate the size and shape of areas within which no resolution is possible, let us call these *one-pip areas*. Notice that the range resolution does not vary with range as long as the same range scale is used. Also notice that the width of the

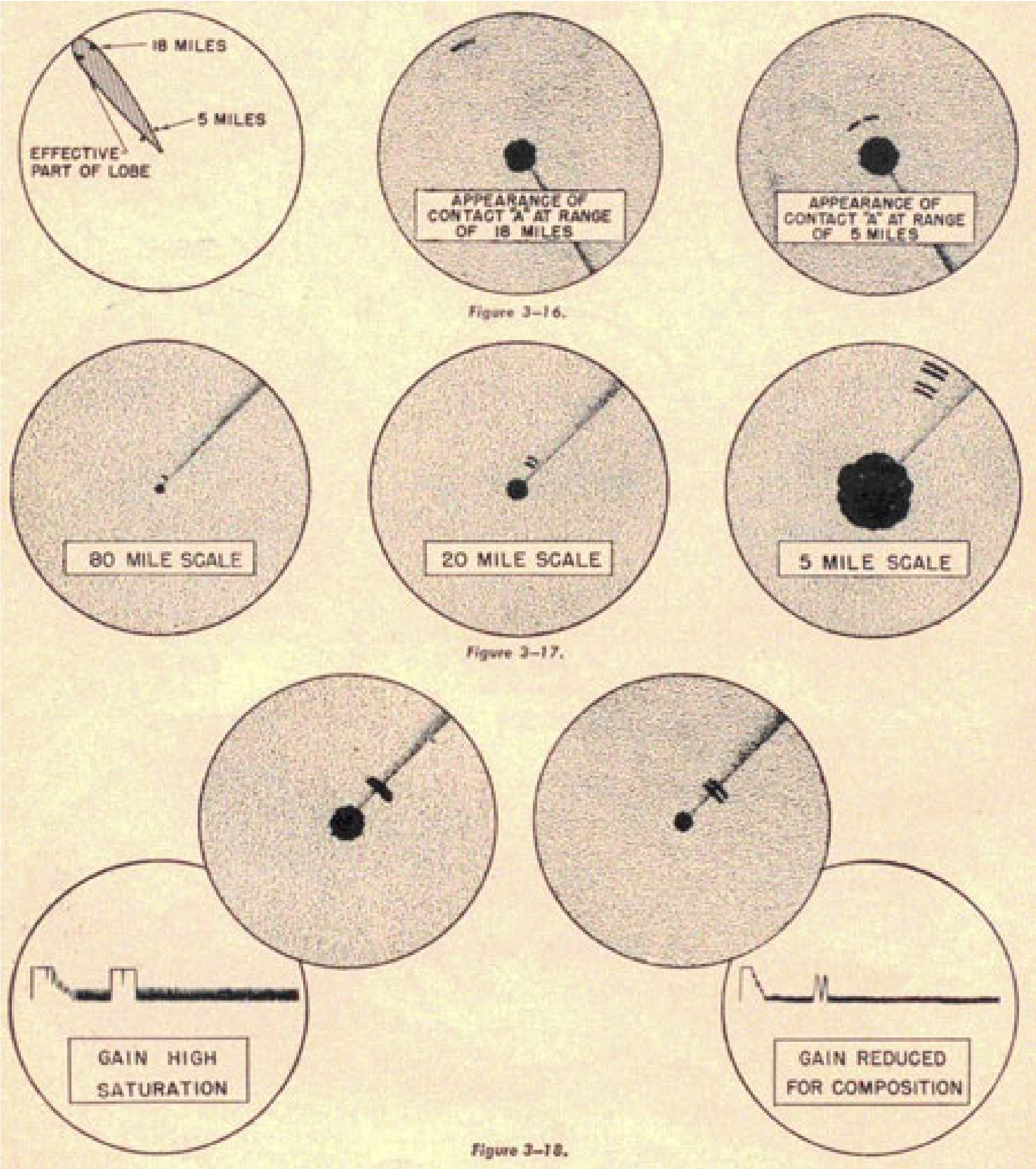

Figure 3-18.

PIPOLOGY

one-pip areas increases with range, the bearing resolution expressed as an angle does not vary with range, but the actual width or intercept of this angle does increase. Therefore, the one-pip areas are narrow at short ranges and wide at long ranges. For any given range, there will he a one-pip area of a certain definite size and shape, and if you detect a group of ships at that same range, they will give only one pip (no matter how many ships there are) if their disposition can be completely fitted into this area.

Now let us consider the figure 3-19. The group of ships when at long range just fits inside the one-pip area of the PPI, and as a result only one pip will be seen on that indicator (this would be true of 300 ships too, if they were disposed within the one-pip area). However, two pips will be seen on the "A" scope because the one-pip area of that scope is smaller and the disposition cannot be contained by it. In this case targets A and D will show as one pip which can be resolved in range from another pip formed by B and C. Thus by using the "A" scope you know there are at least two contacts instead of the single one shown by the PPI.

After this group of ships closes to a shorter range you will be able to tell much more about its composition. Even the PPI will then show three pips. Since B and D can be enclosed by the one-pip area they will give only one pip. When B and D are in the no-pip area, neither A nor C can fit in it; therefore, they will be resolved, and three contacts will be seen: A, B-D, and C. The "A" scope again shows its superiority in the field of composition. Notice how small its one-pip area is at this range. Only one ship at a time can be enclosed by it, with the result that four separate contacts can be recognized, In other words each contact can he resolved from the next in both range and bearing.

What is the significance of this discussion? For one thing, the superiority of the "A" scope for composition reading is established. Furthermore, you now realize that the smaller the area occupied by a disposition of ships, the closer you will have to approach that disposition to tell by radar how many ships are in it. Finally you realize the importance of checking composition frequently as the range closes. At any instant one pip may become several.

Incidentally, the reverse of this is true even in the case of a closing contact, if the ships comprising that contact suddenly form a smaller disposition. Radar operators have reported ships sunk, because they did not realize that there is more than one way for two pips to become one pip.

Estimating the number of planes.

One aircraft contact gives a narrow pip which bounces wildly and irregularly. A large plane echo, however, will bounce less erratically than a small one, just as a pip from a large ship will bounce less than a pip from a small ship.

Two planes will usually give a slightly wider pip (wider in range or bearing), and the pip will rise and fall more slowly and regularly. The echo of three or more planes in formation will have an uneven, jigging motion, distinctly different from two planes in that it is not regular. The echo will not decrease to or near zero, but will vary at near maximum height.

The number of aircraft can be approximated in larger formations by counting the number of individual pips and multiplying that figure by three or four (this will give only a rough approximation of

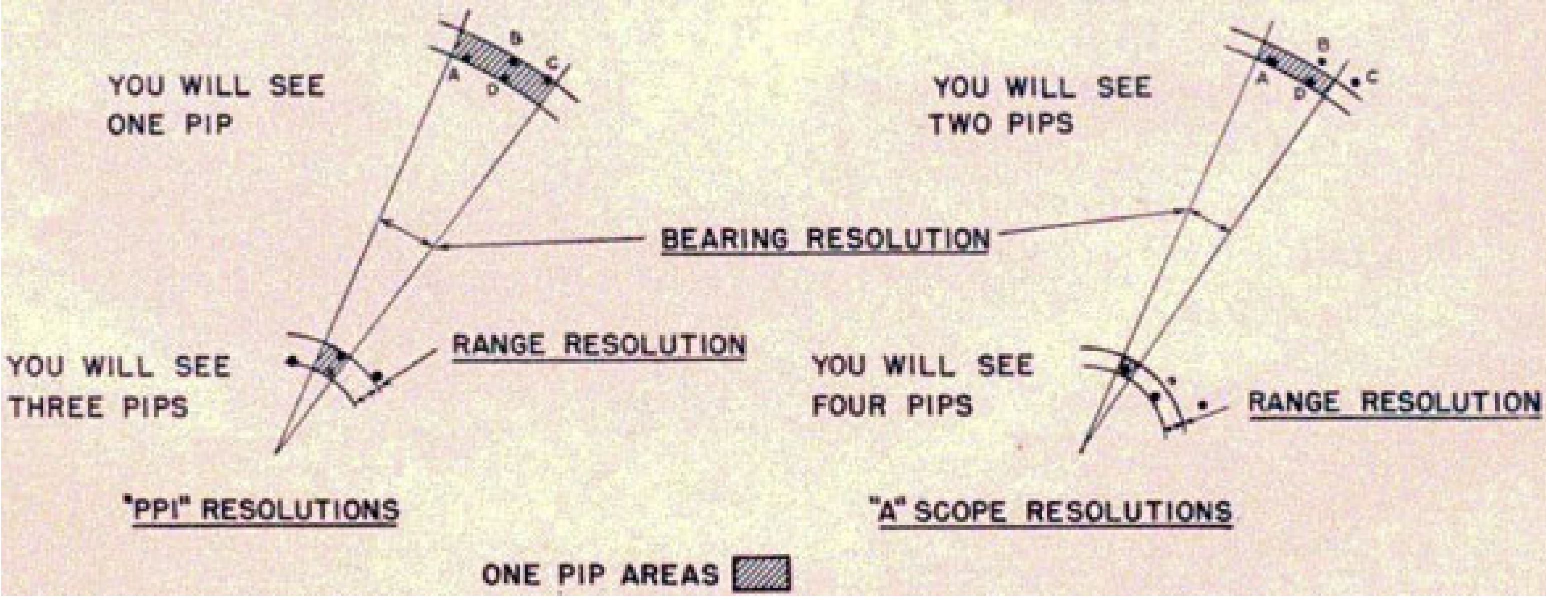

Figure 3-19.

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course). The size of raids can also be estimated, using the PPI. You may become quite proficient at this if you take every opportunity to check your estimates.

An air-group contact may represent planes at some certain altitude, or it may represent a "stacked raid" (planes coming at more than one level). If the group contact divides somewhat so that you can recognize two separate groups, try to determine whether or not they fade at the same range. If they do not, they are not at the same altitude.

General hints on composition.

Inasmuch as air-search radars can detect surface targets, and surface-search radars can detect air targets, a few hints on recognition of these targets will be of value.

Land targets :

1. Not moving according to geographic plot,

3. Speed less than 50 knots (see RADFIVE for target speed determination).

4. Narrow tent-shaped pip compared with land, although a big rock may resemble a ship in this respect.

Plane targets :

1. Speed is greater than 50 knots.

2. Rapidly bobbing pip.

3. Fades appear periodically on long-wave air-search radars. (The reason for this is explained in Part 1.)

4. One plane gives a narrow, quickly bobbing pip.

5. Two planes together give a regularly bobbing pip.

6. A mass flight may give one or several large (high and/or wide) rapidly bobbing pips. Sometimes it is possible to count individual planes by breaks in the peaks of pips.

although the contact moves on the radar scope due to own-ships motion.

2. Pip does not bob like a moving target pip.

3. Should be at expected positions.

4. Usually cover greater area on screen than other targets.

5. Separate pips do not move relative to one another.

Ship targets :

1. Pip height bounces at fairly slow rate.

2. There are normally no fades except when range becomes too great.

FALSE CONTACTS

Many pips appear on radar scopes that are false in the sense that they resemble ship or plane pips but are not caused by ships or planes. Report them, but say that you think they are false, and give your reasons.

Sea return.

The pips shown in figure 3-20 are produced by the radar pulses reflecting from nearby waves. These pips are constantly shifting position, and appear as rough.

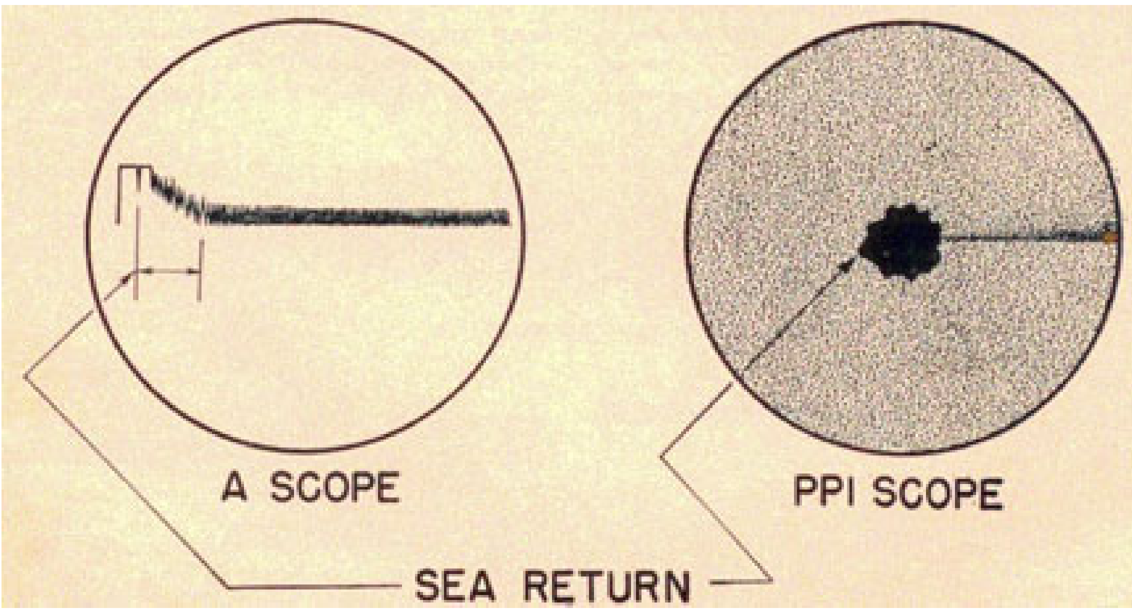

Figure 3-20.

PIPOLOGY

high grass. The rougher the sea, the stronger the reflection (called sea-return) will be. In a very rough sea, the sea-return may extend 4,000 to 5,000 yards in range from you.

Minor lobes.

The beam of radio waves sent out is not perfectly shaped like a searchlight's beam. Actually, if we could view the beam as we can a light beam, it would appear somewhat as shown in figure 3-21 (viewing it from above). We have the main lobe in the direction the

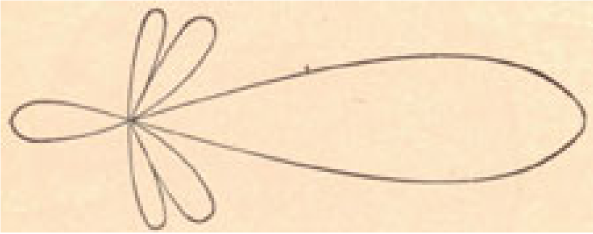

Figure 3-21. Major, minor, and back lobes.

antenna is pointing, and a series of smaller lobes, not wanted but unavoidable, pointing in various other directions. When these smaller lobes (called back and side lobes) illuminate a target they also produce echoes, especially if the target is large and fairly close. These minor lobes seldom reach out more than 6,000 or 7,000 yards, except when they strike high land. They produce a picture on the PPI as shown in figure 3-22.

Note that all pips are at the same range. The largest pip is the actual target; all others are minor-lobe echoes. The minor-lobe echoes may be eliminated by cutting down the gain, but that of course, may also eliminate other small targets from the screen,

Clouds.

The radar at times acts as a weather prophet since it indicates clouds, fog, rain squalls, and regions of sharp temperature differences. Some clouds are not visible to the eye; they are called ionized clouds, although this is a misnomer. Often an echo from a cloud resembles an ordinary pip from a surface target, and at night might lead to a wild goose chase" if it were not investigated further. Course and speed of the target should he determined by tracking it. If its course and speed agree with the wind's direction and speed you might suspect it to he a cloud. Unfortunately, upper air currents sometimes differ in direction and speed from those at the surface.

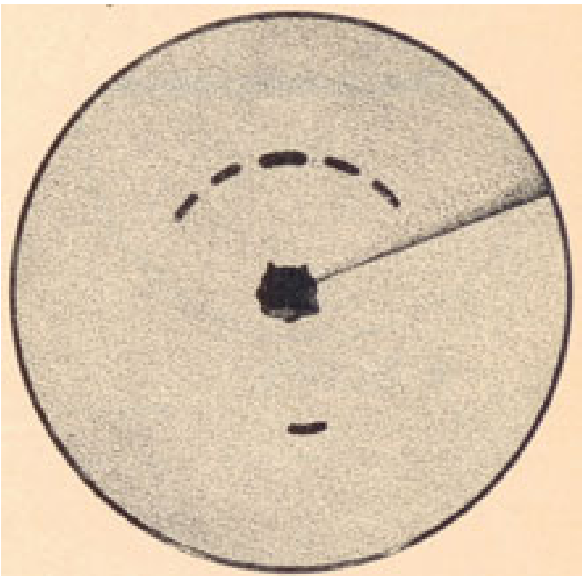

Figure 3-22. Minor lobe echoes.

More positive identification may he obtained by training on the target with the fire-control radar to

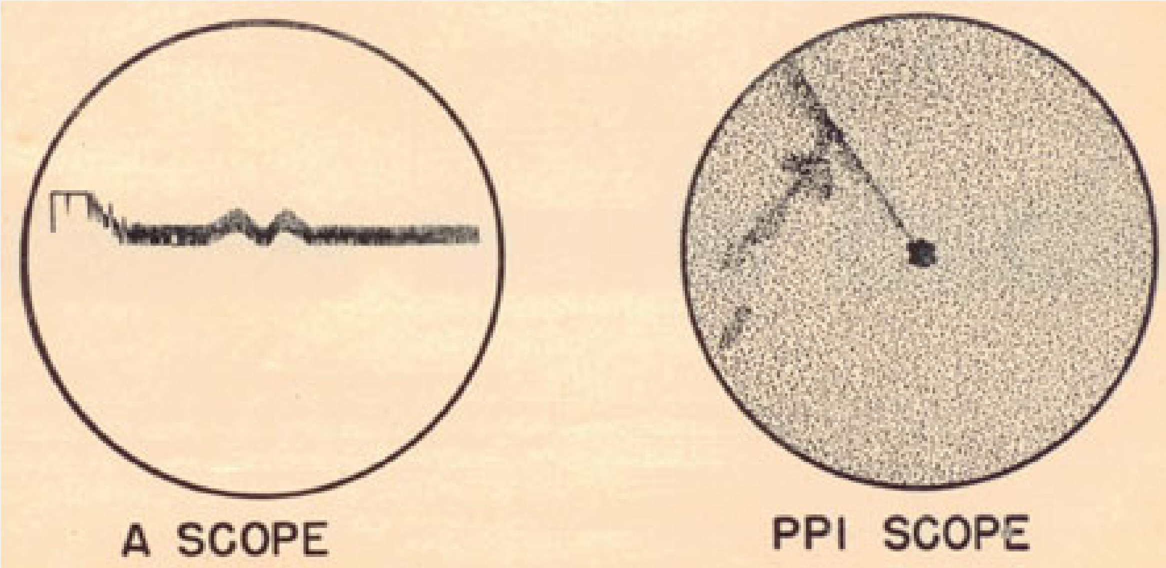

Figure 3-23. Rain squall.

determine whether it is on the surface or has a position angle indicating an air target.

A rain squall or fog bank may usually be identified by the type of pip produced on the screen. It will be wide in bearing and thick in range; since neither rain nor fog forms a solid reflecting surface, the pip produced is of a fuzzy, lacy nature. A typical rain squall might appear on the range scope and PPI as shown in figure 3-23.

The sketches in figure 3-24 indicate the type of picture which will be seen. If the interfering radar pulses do not move, they may obscure target pips. Some sets are provided with a front panel control of the repetition rate, and any change in rate will cause the interfering pulses to move and keep moving. At times the intricate patterns produced on the PPI may in themselves be interesting, but the experienced operator becomes so accustomed to such interference that he hardly notices it.

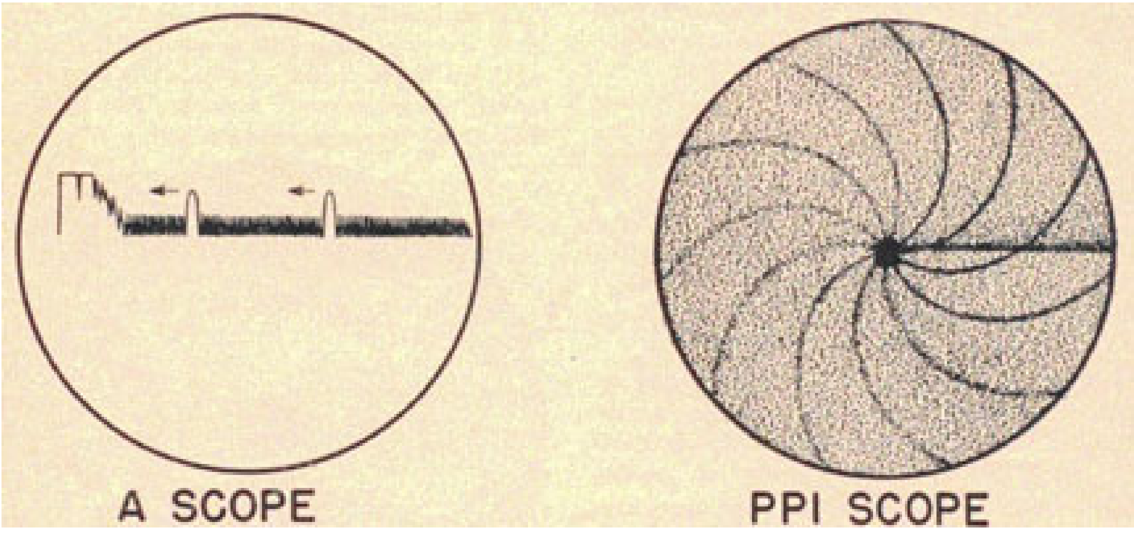

Figure 3-24. Radar pulse interference.

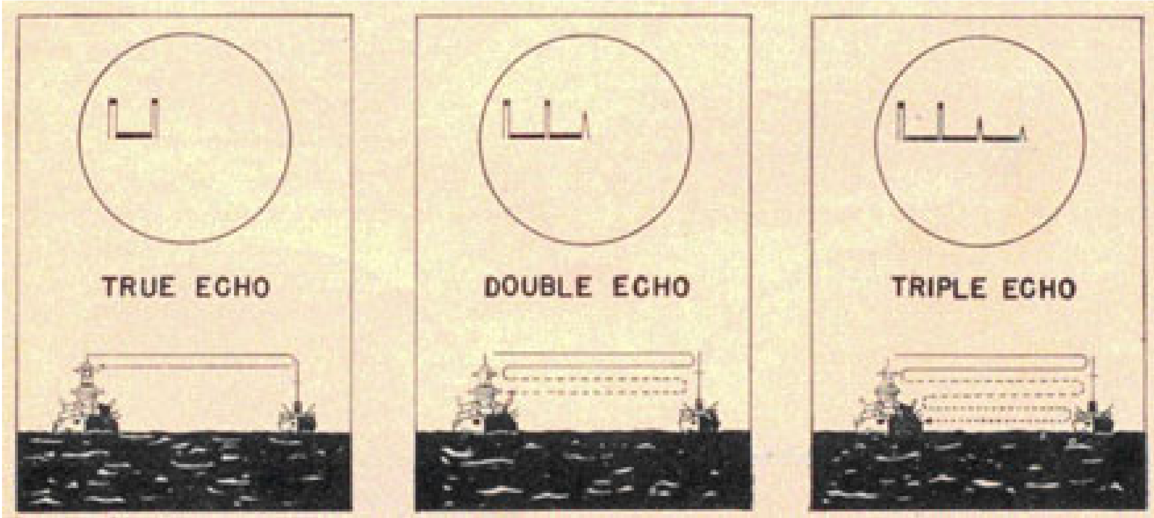

Figure 3-25. Multiple-range echoes.

Radar pulses.

Often pips which move rapidly across the screen are seen: there may be one or several. They are usually caused by another radar transmitter of the same wave length, and may have the appearance of telephone poles as viewed from the window of a moving train.

At long ranges the radar interference will be picked up only in the direction of the interfering radar transmitter. At close ranges the interference will appear at all hearings. Radar interference will always be picked up at a range considerably greater than the range at which a returning radar echo may be detected. Hence

you might pick up another ship's radar in this way long before its echo appears.

Double-range echoes.

Double-range (or double-bounce) echoes are most frequently detected when there is a large target at comparatively close range abeam. Such echoes are produced when the reflected wave is sufficiently strong to make a second or third round trip, as shown in figure 3-25. Double-range echoes are weaker than the main echo, and appear at twice the range. Triple-range echoes are so very weak that they are seldom seen at all. You recall from Part 1 that these echoes are an aid in determining zero-set errors in radars.

Second-sweep echoes.

range, whereas the range indicated for a legitimate first-sweep echo will not be affected by changes in repetition rate. The repetition rate of the SC radars is variable, but do not under any circumstances try to vary the rate of the Mk.3 or Mk.4, since such action would upset the accuracy of range calibration. In any event, this false contact is so rare that you may never see it.

Reflection echoes.

Reflection echoes are sometimes seen, due to the radar wave being reflected from some surface aboard your ship. It results in a contact at the correct range but the wrong bearing. This type of echo only occurs when the antenna is on a certain *relative* bearing. You should know the relative bearing of your particular installation which is subject to this

Second-sweep echoes appear only on some radars (never on the SC, SK, SA, but sometimes on SC, Mk. 3, Mk. 4, and other sets with high repetition rate). They are caused by echoes from targets at long range; in fact, from such a tong range that the echo from pulse 1 returns after pulse 2, and the echo from pulse 2 returns after pulse 3, etc. Since they must come from contacts at a greater distance than that indicated on your scope, their pips are usually smaller than you would expect at the indicated range. Usually they will be from land targets, since that is about the only target that can be seen far enough away to appear as a second-sweep echo. Find out if there is any land in the direction of a suspected second-sweep echo.

If you vary the repetition rate of your radar, the second-sweep contact will move to a new indicated

ENERGY REFLECTING OFF MAST

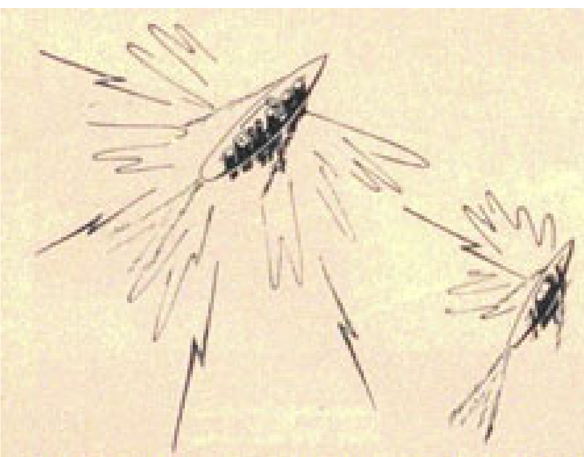

Figure 3-26. Antenna bearing 180 degrees relative; target bearing 080 degrees relative.

fault.

Wakes.

The wakes of nearby large ships will he detected by your radar from time to time, especially during turns of the target ships, and when running at full speed. They are small, ill-defined contacts on the PPI, near to but astern of the ship contact causing them.

Miscellaneous objects on the surface.

Unexplainable echoes, usually at very close range, may be from whitecaps (beyond the sea-return in the direction from which the wind is coming), from birds, from floating objects such as large metal cans or shell cases, and from seaweed.

PPI INTERPRETATION

Radar shadows.

In order to visualize land nearly as radar "sees" it, imagine yourself looking down on an area from a point high in the sky above it, at about the time of sunset. The beam of light from the low sun illuminates the parts of land that a radar on the same bearing would "see" but of course there will be shadows in the hollows and behind the mountains. These same areas will be in "radar shadows" and therefore not detected by the radar. So much for the points of similarity between these two pictures. Now let us analyze the differences.

Beam-width distortion and pulse-length distortion.

Two types of distortion are always involved in PPI presentation. One is due to the diverging beam of the radar, and can be called**beam-width distortion**.

RADAR OPERATOR'S MANUAL

The other is due to the fact that the pulse is not instantaneous (although very short indeed), and it can be called *pulse-length distortion*. Beam-width distortion results in the widening of all things detected by radar; that is, all contacts appear to spread to the left and right of their actual positions. The stronger the echo, the greater the spread. This is more noticeable on long-wave air-search sets because of their wide beam width than it is on micro-wave sets. The result of pulse-length distortion is increased depth of target pips on the range axis of the scope. For example, a small navigation buoy may give a pip 300 yards deep on the "A" scope. As you probably have noticed on the PPI, contacts spread in bearing more than they thicken in range. This becomes increasingly apparent as range increases.

Have you ever noticed that a straight shore line often looks crescent-shaped on the PPI The effect is noticeable on any radar at times, but is most pronounced on long-wave air-search sets. The slight crescent-shaped effect is due to beam-width distortion. Notice in the drawings of figure 3-28 that the coast-line distortion is negligible at points where the shore is at right angles to your line of sight, but as this angle decreases, the shore-line distortion increases is shown, reaching a maximum at Various points of tangency.

Side-lobe ringing.

At times the crescent-shaped effect is so noticeable that according to the PPI, you seem to be in the lagoon of a coral atoll or land-locked harbor, when actually you are off a fairly straight but mountainous coast line. This complete ringing effect will be noticed only on long-wave (air-search) sets; it causes much concern among fighter director officers and others concerned with air defense. This effect is due to a combination of two things. One is the beam-width distortion already mentioned and the other is side- and back-lobe contacts.

Low land.

Radar frequently fails to detect low-lying and gradually sloping land, especially at long range. This results in another distortion of a coast line.

Ships near shore.

Ships or rocks close to the shore may blend with it and either lose their identity completely or appear as a bump on the coast line. The effect is due, of course, to the spreading of all contacts in both bearing and range. A ship may hide from radar by getting very close to shore at any point, but the best place to escape radar detection would be at a point of tangency near the shore (the higher the better with relation to the radar's position).

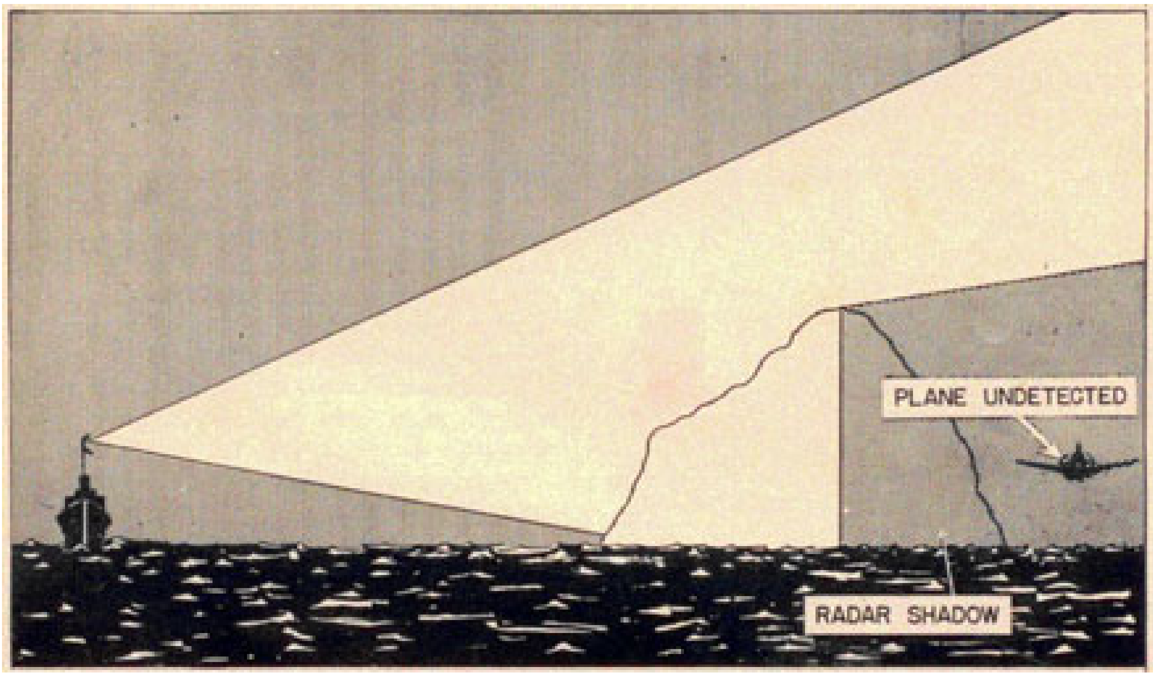

Figure 3-27. Radar shadow.

PIPOLOGY

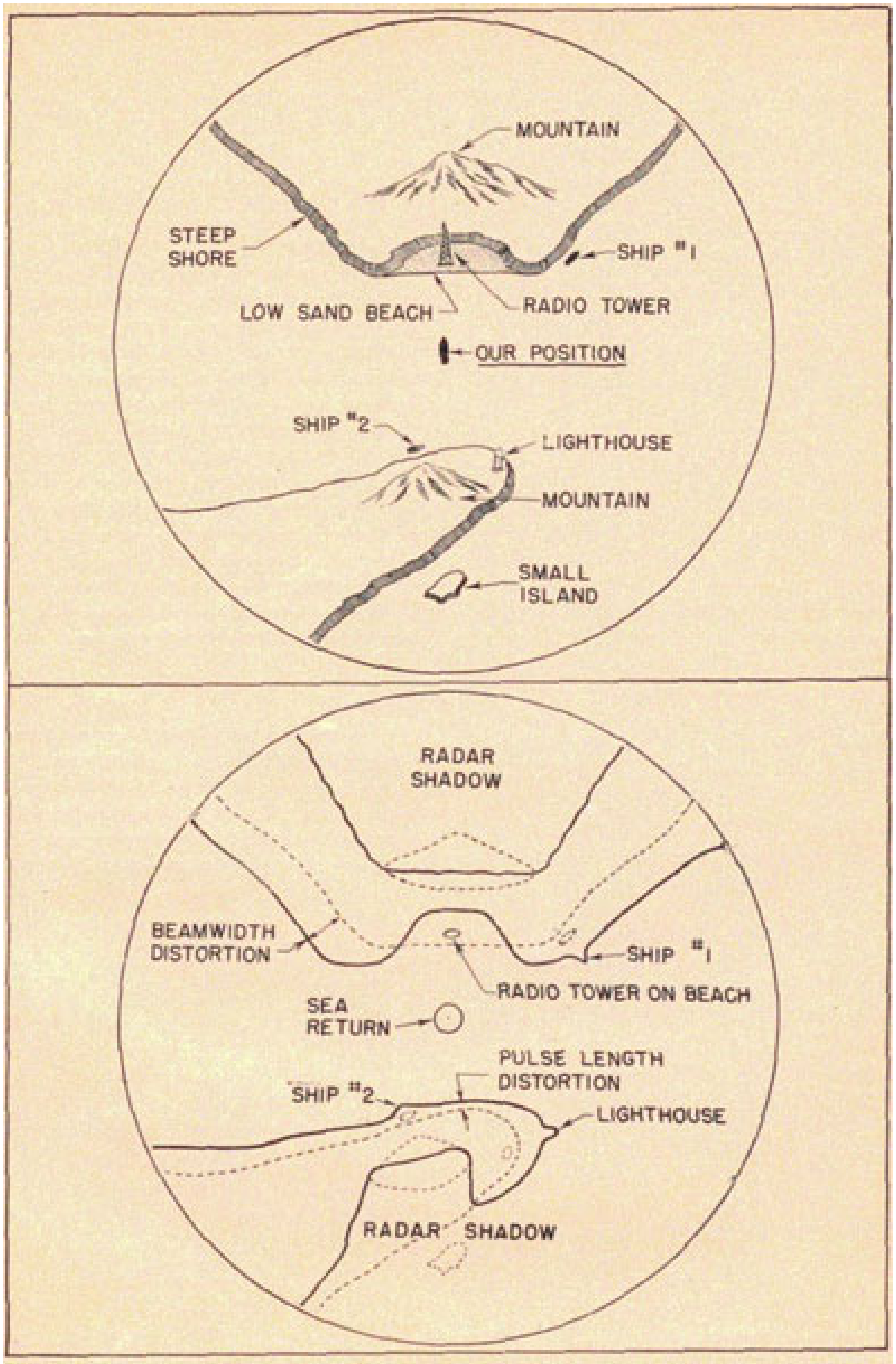
MOUNTAIN
STEEP SHORE
SHIP #1
LOW SAND BEACH
RADIO TOWER
OUR POSITION
SHIP #2
LIGHTHOUSE
MOUNTAIN
SMALL ISLAND
RADAR SHADOW
BEAMWIDTH DISTORTION
SHIP #1
RADIO TOWER ON BEACH
SEA RETURN
PULSE LENGTH DISTORTION
SHIP #2
LIGHTHOUSE
RADAR SHADOW

Figure 3-28.

Consideration of these various factors, and reference to topographical data on the land to be approached, will help you to form a mental picture of what will appear on the scope. Likewise, it will be necessary for you to refer to topographical data to interpret strange land masses. The two drawings in figure 3-28 illustrate and summarize the various distortions that have been discussed. The first shows the actual shape of the shore line and the significant topographical details. Notice also the radio tower on the low sand beach, the two ships at anchor close to shore, and the lighthouse. The second drawing shows (in heavy line) approximately how the land will look on the PPI. The dotted lines represent the actual shape and position of all targets. Notice these things in particular:

1. The low sand beach is not detected by the radar.

2. The tower on the low sand beach is detected but it looks like a ship in a cove. At closer range the low land would be detected and the cove-shaped area would fill in; then the radio tower could not be seen without reducing receiver again.

3. The diverging radar shadow behind both mountains. Distortion due to radar shadows is responsible for more confusion than any other factor. The small island does not show for this reason. Notice also that the back half of the mountains does not show.

4. The beam-width distortion (the spreading of land in bearing). Notice that it is maximum at points of tangency. Look at the upper shore of

7. The lighthouse looks like a peninsula due to the fact that it gives a better echo than the land it is on, and consequently spreads more in bearing (due to beam-width distortion) than the echoes from land.

MISCELLANEOUS CONSIDERATIONS

Course changes.

In many cases you can tell when a target changes its course before this fact is revealed by the plot. The change is indicated by an increase or decrease in the strength of the echo, and is due to increased or decreased *presentment*. For example: a target may be seen end-on, giving an E-2 echo, but when the same target changes course so that you are facing its broadside, the echo suddenly increases to E-4. You will not usually be able to notice any difference in the echo strength as a result of small changes in target course; therefore any sudden, noticeable change in the echo will indicate a substantial course change. You should report this without delay, even though you cannot tell which way the target has turned. The fact that it has changed course at all will often be significant.

Blind sectors.

You have been told that radar shadow always exists behind objects that reflect radar energy. Naturally then, unless your antenna is higher than any other part of your ship, it is possible that a blind sector may exist on some relative bearing due to the effect of such radar obstacles aboard your own ship as

the peninsula and notice that the shore-line distortion (due to beam-width distortion) is greater at the left than at the right. This is because the angle between the radar beam and the shore line is smaller at the left than at the right.

5. Ship 1 looks like a small peninsula. Her contact has merged with land, due to beam-width distortion. If land had been a much better radar target than the ship, the contact due to the former would have completely covered that due to the ship.

6. Ship 2 also merges with the shore and forms a bump on it. In this case she has merged with land due to pulse-length distortion (range spread). Reducing receiver gain might cause her to separate from land if she was not too close to shore.

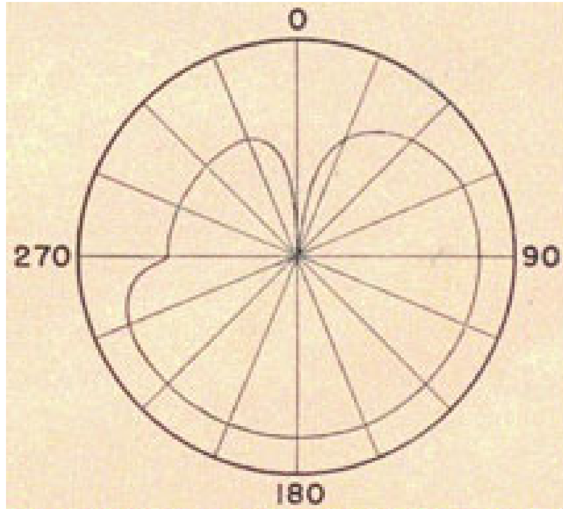

Figure 3-29. Graph showing blind sector.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

super-structure, masts, or other antennas. If you have a blind sector you should know exactly where it is.

One way to check for blind sectors is to keep your antenna trained exactly on some steady land target while "swinging ship" through 360 degrees several times. It will be easy if your radar is a true-bearing type, since the antenna will stay on the target as the ship swings. A graph may be made using polar coordinates, showing echo height versus relative bearing of the chosen land contact. It might be useful to attach a temporary scale to the A scope to assist in determining the relative strengths of the an approximation of the radiation pattern can be obtained by noting the relative strength of sea-return from different bearings. The sea should be fairly calm, since a heavy sea would give a false indication of the pattern; that is, greater reflection would occur from the wave fronts than from the troughs regardless of the actual radiation pattern.

From the foregoing discussion it can be seen that there is more to learning to be a to radar operator than just studying the information in books. It is going to take a lot of actual work on the apparatus itself, but operating time alone means nothing unless you get into the habit of thinking, observing, and remembering, making predictions and checking them, and looking for small details. Radar operating is an art.

echoes. An illustrative graph is shown in figure 3-29.

Such a graph will enable you to estimate which relative bearings are partially blind to your radar. Several graphs should be made before the final pattern is determined. If it is impossible to utilize a land echo,

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

INTRODUCTION

The enemy has two purposes in using radar countermeasures: first, he hopes to prevent us from obtaining any accurate or useful information about his forces by the use of our radars; and second, he wishes to get information about our forces by listening to our radars. The radar countermeasures methods that may be used in accomplishing these purposes are of four types: interception, jamming, deception, and evasion.

Interception is the detection of radar signals by the use of a special receiver. By this means, the enemy learns of our presence in his vicinity, obtains an approximate bearing on our position, and he may determine some of the characteristics of our radars.

Jamming is the deliberate production by the enemy of strong signals for the purpose of hiding his movements or position from our radar by obliterating or confusing the echoes on our indicators. The jamming signals may be produced by a modulated radio transmission, which is electronic jamming, or by echoes returned from many small metal strips, termed Window.

Deception is the deliberate production by or postpone radar detection, or to avoid revealing the true position of an attacking force. If attacking enemy planes take evasive action, it may be impossible to determine the height at which they are flying, or the planes may be detected too late for an adequate defense to he made ready.

VULNERABILITY OF RADAR TO COUNTERMEASURES

Interception.

Radar pulses become weaker as they go away from the radar. Only a small fraction of the energy of these pulses is reflected by the target. This small amount of energy becomes even weaker in returning to the radar. At ranges where the pulse is too weak to return a useable echo, the pulse may still be strong enough to be detected by a receiver. Thus, if the enemy has receivers for listening to our radars, he will be able to detect our forces at ranges greater than those at which we can detect him by radar. In addition to detecting our radar, the enemy can also determine our radar frequency, pulse repetition rate, pulse duration, and whether or not lobe switching is used, and use these data for subsequent countermeasures operations. It may also be possible for the enemy to estimate the size of the force near him by noting the number of signals intercepted, or to analyze the intercepted signals as a means of telling whether or not he has been detected by our radar.

The coverage of a radar can be charted by intelligent use of intercept receivers if the radar operator

the enemy of false or misleading echoes on our radar by the radiation of spurious signals synchronized to the radar, or by the reradiation of radar pulses from extraneous reflectors. Small targets may be made to appear like large ones or echoes may be made to appear where no genuine target exists.

Evasion consists of tactics that are designed to take advantage of the limitations of our radar to prevent

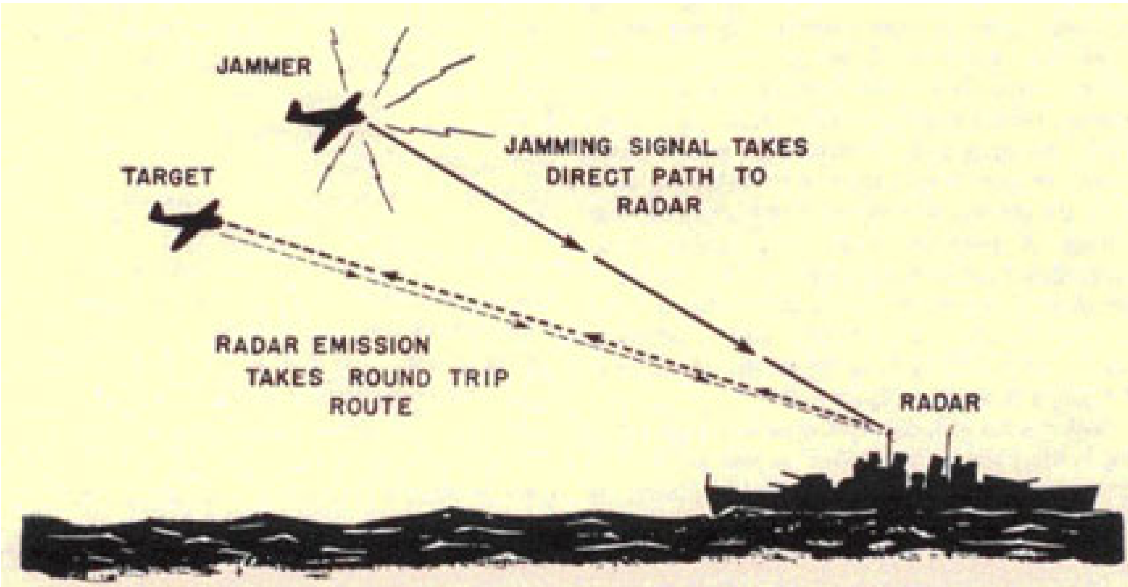

Figure 3-30. Illustration of why electronic jamming is often many times stronger than a radar echo.

is not careful of his operating procedure. For example, one of our radar reconnaissance planes charted a Jap land-based radar completely by flying toward it at various elevations and on various bearings. The Jap operator stopped his radar beam on the plane as soon as it was detected and followed its motion as long at it was in the field of view of the antenna. Thus the complete coverage of the radar was found by interpretation of the intercepted signals. Our radars are also vulnerable to such reconnaissance if the operator stops his antenna on each target as it is detected.

Jamming.

Jamming signals are generated by transmitters that may be carried in aircraft, on ships, or installed at land bases. The transmitter is operated as nearly as possible on the frequency of the radar which it is desired to jam. The signal from the jamming transmitter is usually much stronger than the radar echo, since the jamming travels directly, as opposed to the round-trip path taken by emission from the radar. A strong jamming signal may overload the radar receiver, which necessarily has been designed

Therefore, to avoid giving information to enemy snoopers, keep the antenna rotating.

to be a very sensitive instrument, and therefore it may be rather susceptible to overloading.

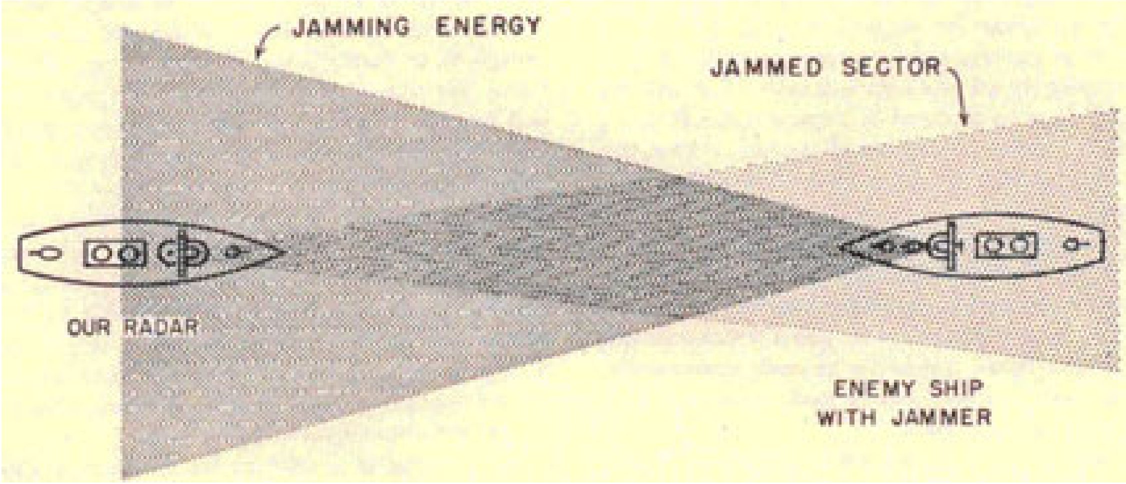

Figure 3-31. Jammer located on target. Target said to be self screened.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

Very often a ship may try to conceal itself from radar detection by carrying a jammer. This kind of jamming, which is illustrated in figure 3-31, is called self screening. If other ships are in company with the jamming ship, the problem of detecting them may be complicated by the fact that the jamming and echo do not come from exactly the same place. Irrespective of the position of the jamming ship relative to the target vessel, a weakness of electronic jammers is that they are not effective within a certain minimum range. When approaching the target, you will first pick up the jamming signal, owing to its high strength. At normal radar range, both jamming and echo from enemy ship will be present, although the jamming may be strong enough to obscure the echo. However, as the range closes, the strength of the echo signal *increases much more rapidly than the strength of the jamming signal*. A point is finally reached where the target pip shows up clearly through the jamming. The range at which this occurs may be between 2 and 8 miles, depending upon the size of the enemy ship and the strength of the jammer. Figure 3-32 shows this condition as related to the range of an approaching aircraft equipped with a jamming transmitter.

When a jammer is not on every vessel to be screened, it is difficult to prevent detection of the force from every direction. For example, in figure 3-33 a very exaggerated case is illustrated. Enemy ships 3 and 5 are equipped with jammers and their mission is to conceal the force. Since enemy ships 3, 4, and 5 all bear the same from friendly ship 1, they are concealed by the jammer on 3. However, a picket ship at 2 may be able to range on some of the targets in spite of the attempt by enemy ship 5 to jam him. Even though some of the ships in a task group are hopelessly jammed, others may be relatively unaffected. Therefore, keep all the radars in operation because the situation may improve as

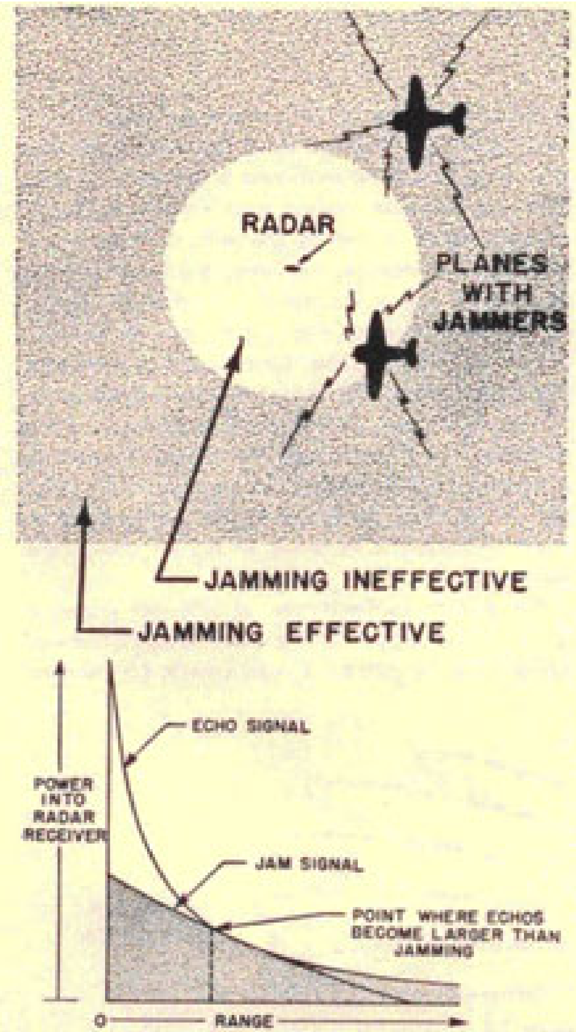

Figure 3-32. Electronic jammers ore less effective at short ranges than at long.

the dispositions of the two forces change.

An aircraft carrying a jammer might pass through a fade zone while echoes from the ship he is protecting are unaffected. This would cause a sudden improvement in echo strength over the jamming, perhaps making more readable echoes that were obscured. This same effect may occur when the jammer is on the ship to be screened, since the antenna pattern of a surface search radar also is broken into many lobes and nulls by reflection of the radiation from the water. The jammer antenna must direct its radiation directly into the small area of the radar antenna, while the radar antenna needs only to cause its pulse to hit some part of the large area of the enemy ship to get an echo back. At ranges where the jammer antenna is in a null of the radar, as in figure 3-34, the jamming is ineffective, but an echo is returned from the superstructure of the enemy ship because the lobe below the null strikes the ship. Thus, it is necessary to keep the radar operating, and to maintain a close watch on the scope when jamming is encountered, because the jamming effectiveness may suddenly be reduced.

Off-target jamming is seldom produced deliberately; it usually occurs because the disposition of the jamming ships changes relative to the vessels they are attempting to screen. Jamming of this type imposes no special problem for most search radars, but if the radar is one that employs lobe switching, bearing

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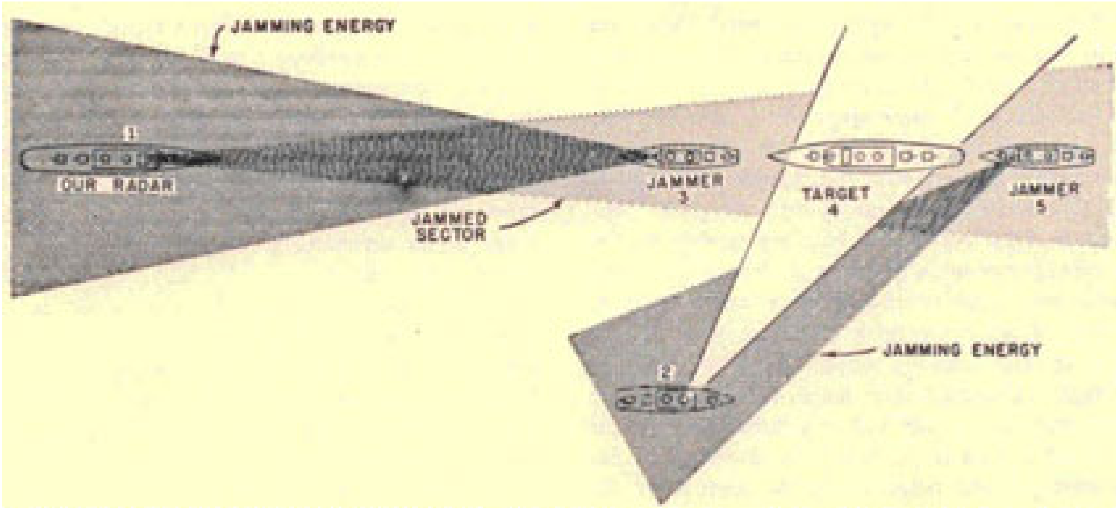

Figure 3-33. Jammer is on same bearing but not on board target. Radar located on friendly ship at 2 is probably free of jamming.

errors may be produced. The error arises from the fact that the jamming does not affect both lobes equally, so that *the matched-pip condition may appear at the wrong bearing*. In radars like the SM and SP, jamming can also produce serious errors in the height measurement. These inaccuracies are greater in some radars than in others because of the nature of the receiver circuits used. In general, however, the errors in angular measurement that off-target jamming produces in lobe-switching radars can be reduced by operating the receiver at the lowest gain setting that allows the pips to be clearly visible. When range information only is desired, better results are obtained with lobe-switching "off". No bearing inaccuracy should occur when the jammer is on the target (self-screening) or on the same bearing as the target. In order to become aware of possible bearing inaccuracy, it is necessary to determine whether the jammer is on or off the target bearing.

If the side lobes of the antenna are large in size, jamming can be received from directions other than the one in which the main lobe is pointed. In some cases, the jamming received in this way may conceal a target which is not on the same bearing as the jammer. For example, in figure 3-35 the radar on the friendly ship is jammed by the off-target jammer so that neither enemy ship can be seen on the PPI. Note that there are three distinct jammed sectors on the accompanying PPI screen, produced by reception in the three lobes as the antenna rotates. If the jamming is not too strong, the sectors of jamming caused by side-lobe reception can be reduced in intensity by reducing the receiver gain. The target in figure 3-35 might be made visible by this simple adjustment.

The relative ineffectiveness of off-target jamming, except against lobe-switching radars, suggests maneuvering until the jammer is in an unfavorable position.

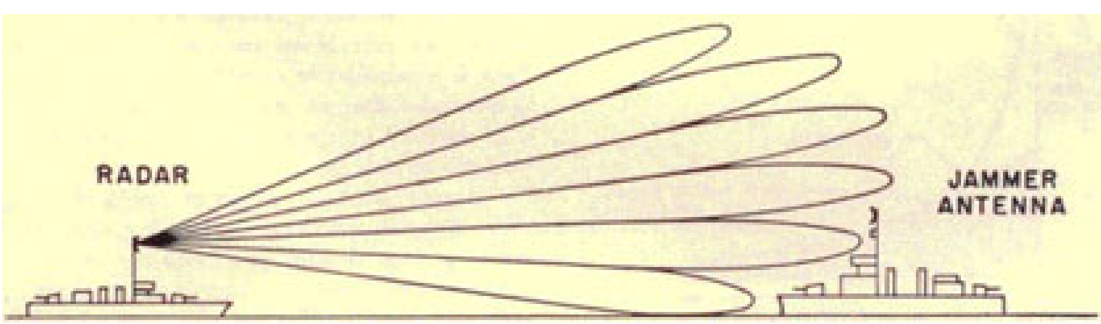

Figure 3-34. Jamming ineffective because the jammer antenna is in radar null.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

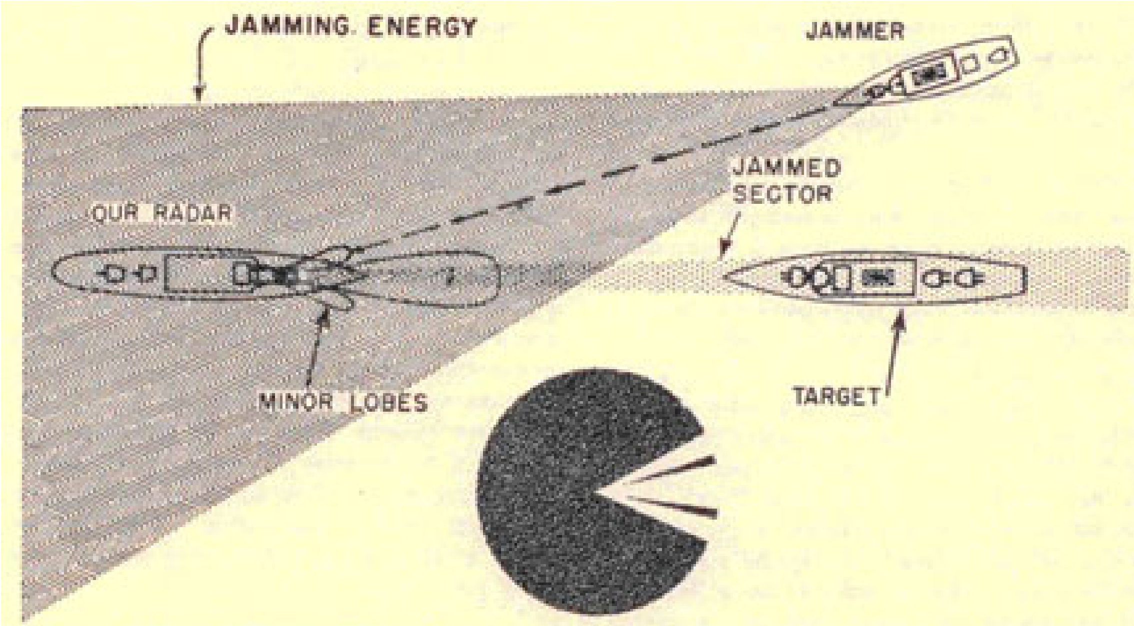

Figure 3-35. Jamming reception in side lobes from off-target jammer.

The enemy will monitor both his own jamming and the signal that he is attempting to jam so that he will know if either changes frequency enough to make the jamming ineffective. He may be expected, then, to train his jamming antenna for maximum jamming, and it will be very difficult for a single ship to maneuver in such a way that the jamming effectiveness will be decreased. However, it is always well to search the areas around the jammed sector in the hope that either the enemy operator is not alert or that some of the ships that he is trying to conceal will have strayed outside the zone of effective concealment. The possibility that the jamming is being used for deceptive purposes must be considered. Therefore, a thorough search must be maintained throughout the full 360 degrees because the jamming may be sent out to attract our attention to a sector away from the direction from which the enemy plans to attack.

This is especially true with regard to the transmitter-weak or erratic emission seriously reduces the chances of the echo signal strength being strong enough to override the jam. Report any falling off in equipment performance to the technician.

The A scope is less vulnerable to jamming than the PPI or B types, and therefore should be used when jamming is encountered. However, in the case of noise jamming, the A scope is little better than any other type of indicator, but it will be found more useful against most other types of jamming. PPI or 13 presentations are preferred only when it is desired to find the bearing of the jammer. It is not desirable to keep the antenna stopped for long intervals while trying to read through jamming on the A scope. All-around search must always be maintained.

Jamming can also be accomplished by the dispersal of many strips of reflecting material, called Window. Since Window jamming consists of a cloud of particles that occupy a definite place in space, the vulnerability of radar to this type of jamming is different from the

Microwave radars are less vulnerable to electronic jamming than long wave types. The narrow beam width allows targets to be seen close to the jammer bearing, and the concentration of high power in a single direction makes for high signal strength relative to the jamming. Adequate jamming is hard to produce against microwave radars because it is difficult to develop high power at these frequencies.

A radar operating at peak efficiency is far less susceptible to jamming than one which is out of adjustment.

vulnerability to electronic jamming. Unlike cases in which electronic jamming is employed, the location of Window relative to any targets which it is supposed to screen is continually changing. Window moves with the wind at a speed approximately 2/3 that of the wind, while the speed of the enemy ship may be greater or less than the speed of the wind. If the Window area is not large, the enemy

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will have difficulty in staying in the Window-infested area because the Window is hard to see in the air. Watch for stragglers outside the infected area. Often they will appear on the windward side of the Window blob.

Window produces pips that are quite similar to those from real targets, whereas electronic emissions fill the scope screen with patterns totally unlike those normally encountered. Also, the reflected signals from Window will occupy only a portion of the trace, while electronic emissions cover the entire sweep.

The first indication of an impending raid may be Window pips on long range search radars, so that the jamming may work against the group responsible for it. With fire control or height-finding radar, on the other hand, properly distributed Window can ruin the accuracy of determination of bearing and height. Because Window can ruin the accuracy of AA fire control radar, the principal use of Window has been against this

the Japanese are familiar with these deception techniques. For example, the Japs have equipped sampans with reflectors, so that they appear to our radars like large craft. The sampans are sent out in advance of a convoy, on courses calculated to lead our ships well out of the way by the time the real targets arrive. Other types of reflectors may be floated or suspended from balloons, and designed to give false echoes like those from submarine periscopes, surface vessels, or aircraft. Many of these devices produce echoes that seem very similar to genuine echoes in their behavior on the scope. Often the only way of revealing the false nature of the deception echo is to plot its track, since most airborne mechanical devices drift down wind at a speed somewhat less than wind speed. Thus, radars are very vulnerable to attack by deception for at least a short period of time. Often this short time is long enough to permit enemy planes to get out of gun range.

Evasion.

Low-frequency radars, such as the SK and other air search sets, can not detect low-flying targets at long range, because the antenna pattern is such that the beam

type of radar as a means of escaping from AA fire after an attack.

If the enemy intends to infect a large area with Window to prevent search or fire control by radar, he will drop packages of it while flying a course that will provide good coverage. A single plane may fly a flat spiral or a figure-of-eight course; when several planes are working together, they may fly straight parallel courses, dropping packages of Window at periodic intervals. Surface craft may infect smaller areas by firing Window-filled shells or rockets. However, to be effective in concealing targets within the Window cloud, the packages must be dropped at close enough intervals that each bundle will not exist as a separate cloud, but that all the Window bundles will blend into one large cloud. The better the range and bearing resolution of the radar, the closer the Window must be sown to conceal the targets within the cloud.

Deception.

Although it is possible to deceive radars by the use of electronic devices, the necessary equipment is difficult to design and operate. Test operations using electronic deception have indicated that the results seldom are good enough to warrant the trouble involved. Since the enemy faces a great problem in this field because we have more radar on more frequencies, it is unlikely that electronic deception will be encountered to any great extent.

However, the use of mechanical devices for deception is entirely feasible, and both the Germans and

does not provide good low cover. The enemy is quite aware of this shortcoming and his air strikes frequently approach "on the deck". Air-search radars are not able to detect changes of altitude nor are they able to detect aircraft flying over land with any certainty. The Jap knows these limitations too, and makes full use of them to avoid detection by radar. These failings are serious, but they will soon be remedied by new equipment that is being produced.

DISTINGUISHING JAMMING FROM INTERFERENCE

Interference is caused by the reception of confusing signals accidentally produced by the effects of either friendly or enemy electrical apparatus and machinery, or by atmospheric phenomena. Interference should not be confused with enemy countermeasures.

Accidental interference from many types of electronic gear and electrical machinery has been noted on radars. The signals may enter the radar receiver by shock excitation of radio antennas or guy wires, through the power line, by way of inter-connecting cables between various units, or because of inadequate shielding of the radar equipment. It is difficult to predict the effects these signals will have on radar operation. In some cases accidental interference may

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

be confused with deliberate jamming attempts. Methods of distinguishing between the two are outlined in the following.

Internal equipment faults. Cluttered scope patterns caused by internal faults in the equipment may be distinguished from jamming or external interference because the scope pattern remains the same regardless of the direction in which the antenna is trained. If trouble persists, *call the technician*. However, with strong jamming the same effect may be observed if the receiver gain is not reduced.

Interference from other gear aboard own ship. It usually is possible to take a bearing on interference of this type. The *relative* bearing will always remain the same, but the *true* bearing will change with changes in the ship's course. If both bearings change, the trouble is not on board.

Pulse interference from other radar. Pulse interference causes light, tall pips on A-scope screens. These pips move back and forth along the trace in a random manner, giving the pattern the name "running rabbits". The spacing between pulses is usually much larger than the width of the pulses.

It is possible to take bearings on pulse interference from other radars in the same frequency band and having approximately the same pulse repetition rate. At short ranges, the indications appear over a large arc of antenna train. The usual method is to consider the center of the arc as the correct bearing, instead of training for maximum strength or neither this pattern nor the one on the A scope causes serious difficulty because the pips are considerably more distinct than the interference, and because of its prevalence, operators soon become familiar with it. However, if the effect is found annoying, it may be minimized by changing the pulse repetition rate of own radar until the most easily read pattern is obtained.

Interference from radio transmitters, beacons, etc. Keyed CW may be read as dots and dashes. Rotating the radar antenna may or may not produce any difference, depending on how the interference is getting into your radar.

Radiotelephone transmitters on board the ship sometimes produces interference, but they may be distinguished by one or more of the methods discussed in the preceding paragraphs. This same type of interference coming from nearby ships may sometimes be very confusing to the operator. Therefore, every effort should be made by the operator to learn to identify it so that he will not confuse communications interference with enemy jamming.

Spark interference caused by commutator or ignition sparking appears on the A scope as a series of narrow, regularly spaced pulses. Interference from spark transmitters, diathermy apparatus, etc., will produce wider pulses, more closely spaced. Generally the train of interfering pulses will move across the screen. Spark interference may blank out the screen of PPI scopes in one or several sectors, depending on the signal strength.

Atmospherics. Returns from rain clouds or other atmospheric condition are not likely to be confused with transmission jamming. They are, however,

distinctness of the signal. This system has been used to home on ships in convoy or on shore installations.

Pulse interference on the PPI results in a series of broken spirals. Under normal conditions,

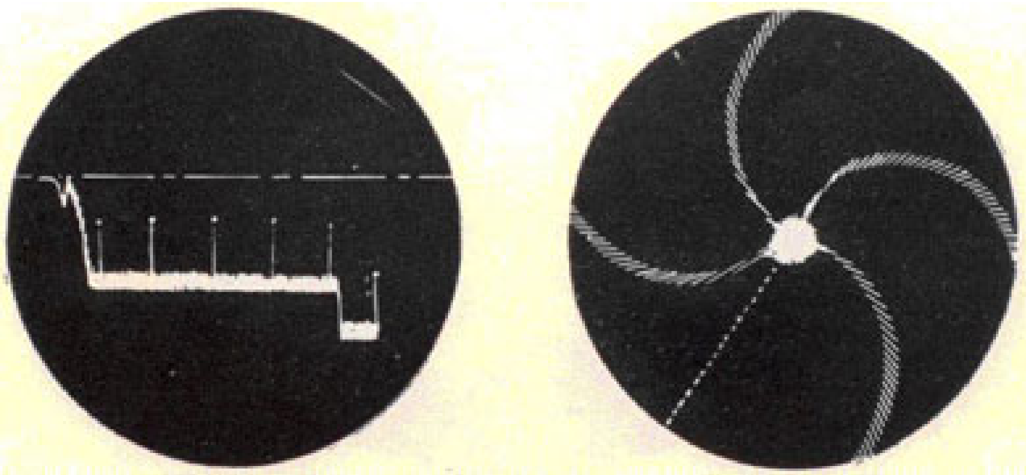

Figure 3-36. Interference from other radars- "running rabbits".

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somewhat similar to Window jamming. The pips produced by storms are often lacy in character on A scopes and may occupy quite a large portion of the

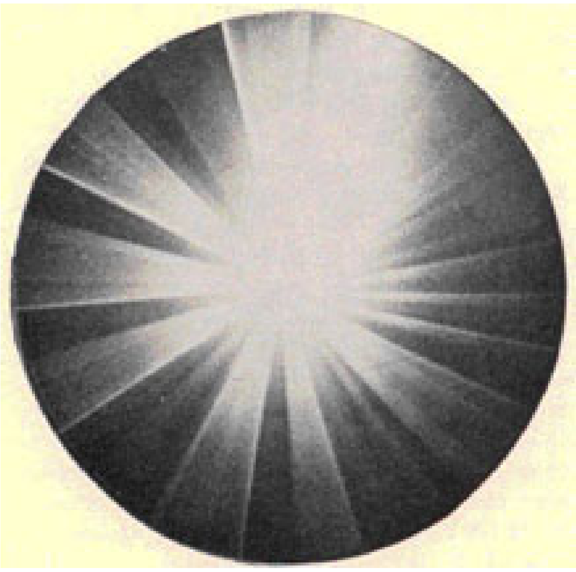

Figure 3-37. Interference produced by keying of radio transmitter on board ship. Note appearance

screen. They show but a slow change in range. The appearance of both cloud and Window echoes differs from that of genuine echoes in the amount of beating that becomes apparent when the receiver gain is reduced, and the motion of the echoes always agrees with the prevailing wind direction. On the PPI, a storm will be indicated by a filled-in area having less definition than a genuine target. Some thunderstorms (the isolated convection type that occur in summer) give solid echoes surrounded by a cloudy haze. These echoes can be wrongly interpreted as real targets.

Lightning has been observed to produce large pulses on P band radar. St. Elmo's fire has also caused severe interference with P band radar on occasion.

CLASSIFICATION OF TYPES OF JAMMING

of dots and dashes and non-directional effect produced. In this case the interference is not entering by means of the radar antenna, but directly into the radar receiver itself.

The two general classes of jamming are (1) the electronic type, in which use is made of a radio transmitter, and (2) mechanical or Window jamming.

Electronic jamming.

Types of electronic jamming may be classified according to the nature of the emission employed by

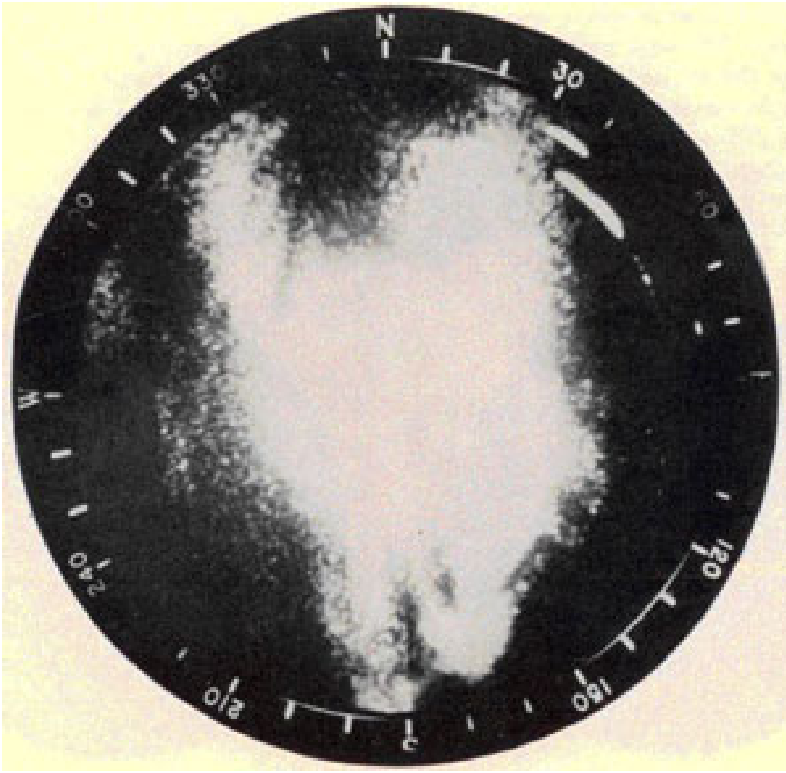

Figure 3-38. Atmospheric Interference.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

the enemy. Any kind of transmissions can he used, although with varying degrees of effectiveness. The list includes unmodulated continuous wave (CW), frequency or amplitude modulated CW, pulsed signals, and mixtures. The modulation frequencies may be high or low, and either synchronized or not to the pulse repetition rate of our radars. We may expect a wide variety of different patterns to appear on our radar scope screens, depending on the particular type of signal the enemy is sending out. Special equipment is needed to identify the exact nature of these

or 240 cycles, the jamming is synchronous. This produces a stationary pattern on radar scopes. Jammers not modulated at an exact multiple of the radar PRR are called non-synchronous, and produce patterns which traverse the screen, causing blurring. An intermediate condition, known as semi-synchronism, results in an erratic stop-go motion. Noise is the only type of modulated jamming which cannot be synchronized.

A second consideration when attempting to distinguish between types of jamming is the

emissions. However, the operator can often obtain enough information from a particular scope pattern to make a good guess as to what AJ measures to apply without delay. Also, it is of obvious benefit to the Navy to receive prompt reports on the kinds of jamming being employed by the enemy.

The first general characteristic the operator may easily note about modulated transmission jamming is whether it is synchronous or nonsynchronous.

Synchronous jamming refers to signals which are modulated at an exact multiple of the pulse repetition rate of the radar against which they are being used. Thus, if your equipment is operating on a PRR of 60 cycles and the jammer is modulated at four times that, approximate determination of the modulation frequency of the jammer. Jamming modulation frequencies may generally be classified as low, medium, or high.

On short range scales, or when using an expanded sweep, the electron beam which traces the time base moves much faster than on long range scales. This means that for a given type of jamming signal, the pattern will be less complex when the indicator uses a short range scale. Changing the range scale has the same effect as changing the frequency of the jamming modulation, so that what appears to be high-frequency jamming on a long range scale may look like low-frequency on the short scale. It is necessary, therefore, to *specify the particular range scale in use when describing a jamming signal*.

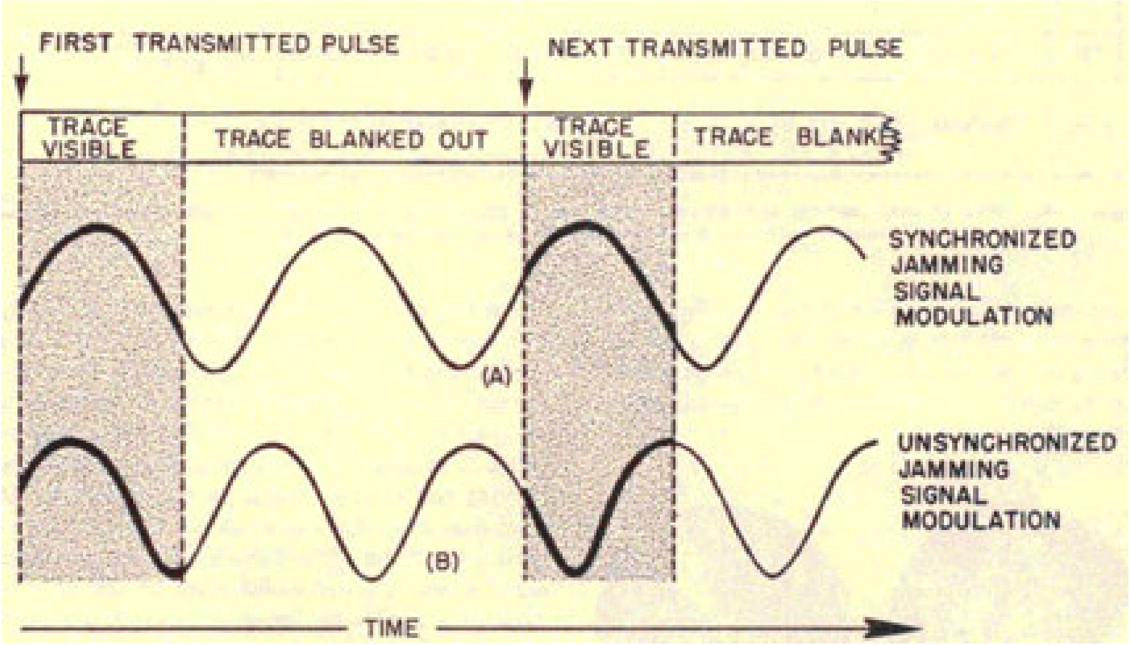

Figure 3-39. Synchronous and non-synchronous jamming. In (A), the same portions of the jamming signal waveform appear during each sweep an the radar scope causing a stationary pattern. In (B) the jamming is an different port at cycle during successive sweeps. This produces blurring an the scope screen.

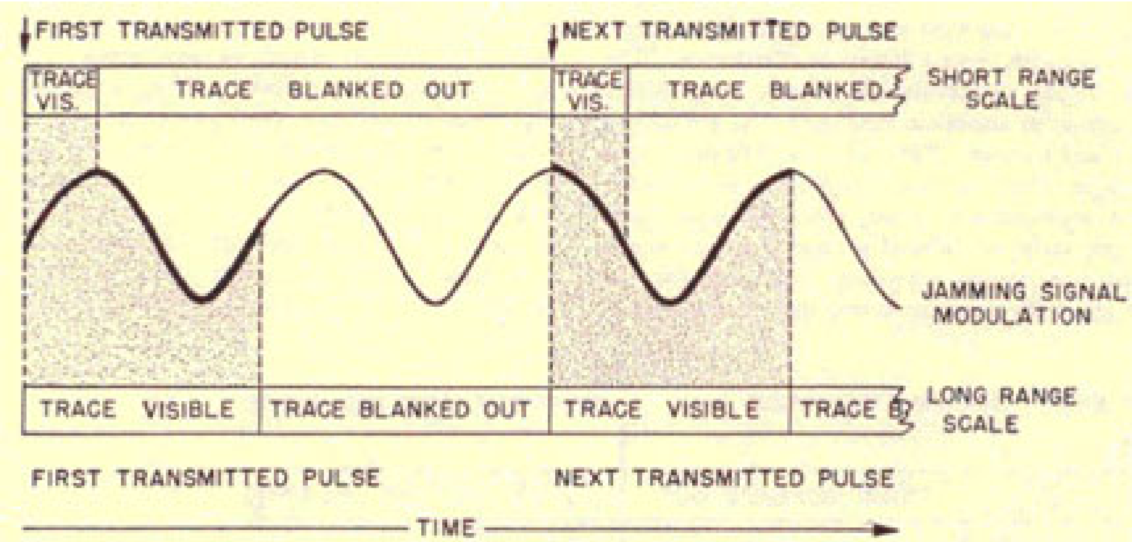

Figure 3-40. Effect of same jamming with different sweep times. The pattern in the tong range will appear to be more complex, because a greater portion at the modulation cycle will appear.

An estimate of the effect of the jamming modulating frequency may be learned by studying the following sketches and their captions. A range scale of approximately 40 miles has been assumed, except where otherwise noted.

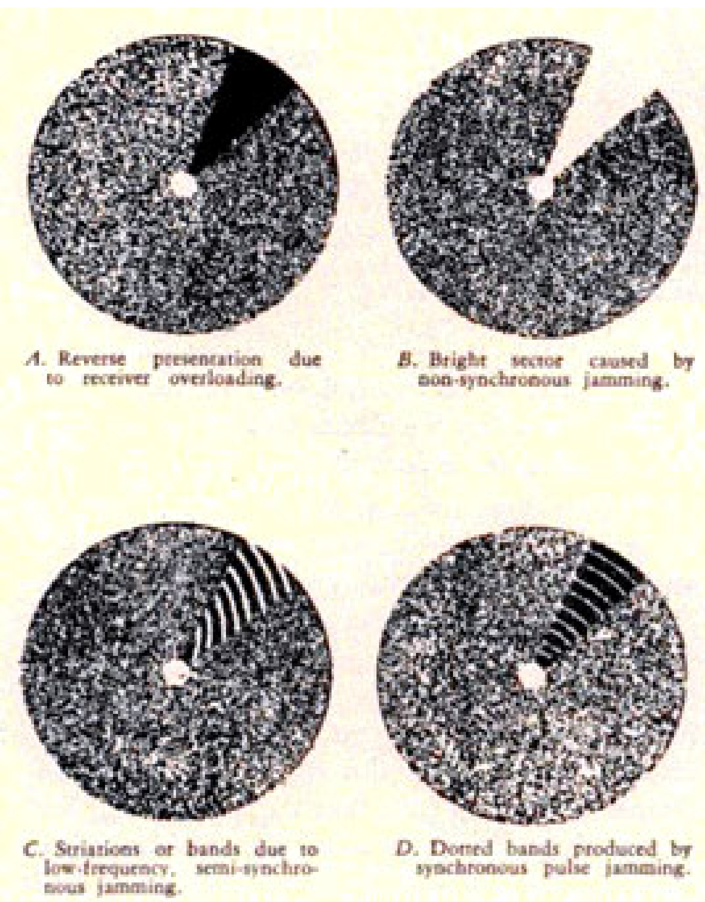

Figure 3-41. The PPI in the presence at jamming.

The text which follows is concerned almost entirely with type A scopes, because PPI and B presentations are less useful for identifying jamming as they react in nearly the same manner to all types. However, a few points on the behavior of PPI scopes may be noted. They respond to non-synchronous jamming by showing one or more bright pie-shaped sectors. If more than one sector appears, the brightest is due to the major antenna lobe and the others result from minor lobes. An overloaded radar receiver is indicated by a reverse or "negative" presentation, with the jammed sectors dark on a light, speckled background. If the jamming signals are synchronous or semi-synchronous, striations (lines) show up on the screen within the jammed sectors.

Unmodulated CW jamming. Weak unmodulated CW jamming (or strong jamming at low gain control settings) causes an increase in both signal and noise level on the A scope. The trace may become distorted, (figure 3-42B), as the radar antenna first comes into and as it leaves the jammed sector. If the antenna were stopped in the jammed sector, the trace would assume a position along the normal base line. It will be noted that the pip is double sided and is more or less "filled-in" depending on how close the jammer frequency is to our radar frequency. As the jamming becomes stronger, both the grass and a single-sided pip may appear below the baseline

(inverted). Finally, as shown in C, complete overload occurs, wiping the trace clean of both pip and grass.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

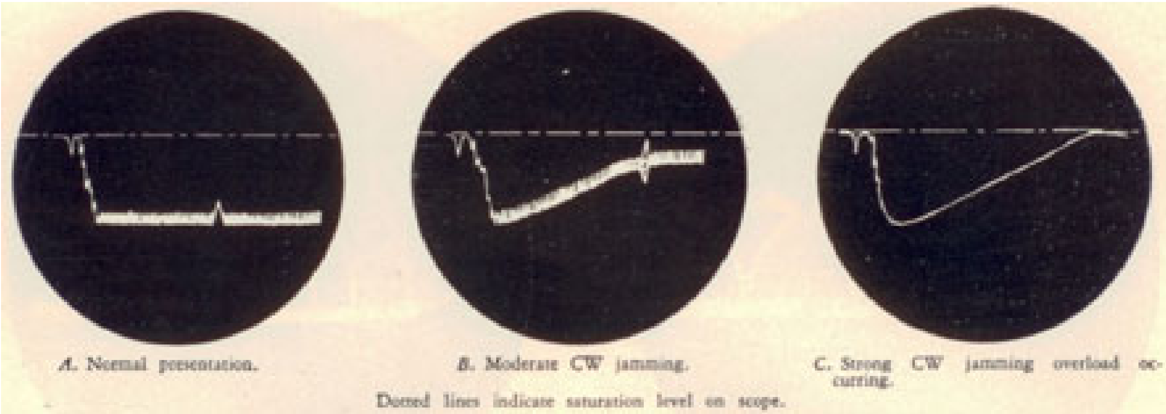

Figure 3-42. Unmodulated CW Jamming.

Unmodulated CW jamming is seldom used, although similar effects may appear due to accidental interference from radio equipment. Often when a small percentage of modulation is used on the jamming carrier wave many of the effects of unmodulated CW will be apparent on the indicator.

Low-frequency amplitude-modulated CW jamming. Somewhere within this region, depending upon the sweep time, the effect known as "tramlines" will occur. Tramlines appear as a number of adjacent, sometimes crossing, horizontal baselines on the A scope. The reason for the multiple pattern is that successive traces are deflected vertically different amounts by the jamming modulations. The target echo will appear on each trace, and it may be double-sided or inverted, as in CW jamming. If unsynchronized, the tramlines move up and down, so as to seem to breathe.

Medium-frequency amplitude-modulated CW jamming. The A-scope presentation produced by this type of jamming is predominantly vertical, even on short range scales. As the frequency is increased, the horizontal or crossing-line characteristic of low-frequency modulation gives way to more evenly spaced, upright indications, usually of constant amplitude. When the pattern is synchronous or semi-synchronous, it is sometimes called "basketweave". The non-synchronous condition is evidenced by blurring, with lines or shading at regular intervals. These do not block out the target indications which run up through the jamming as a vertical line or series of pips which are atop each other, and have greater definition than the rest of the pattern. The echo will also appear on top of the jamming pattern if the gain control is adjusted so that saturation is not occurring. Care should be taken that the earn is not reduced so much

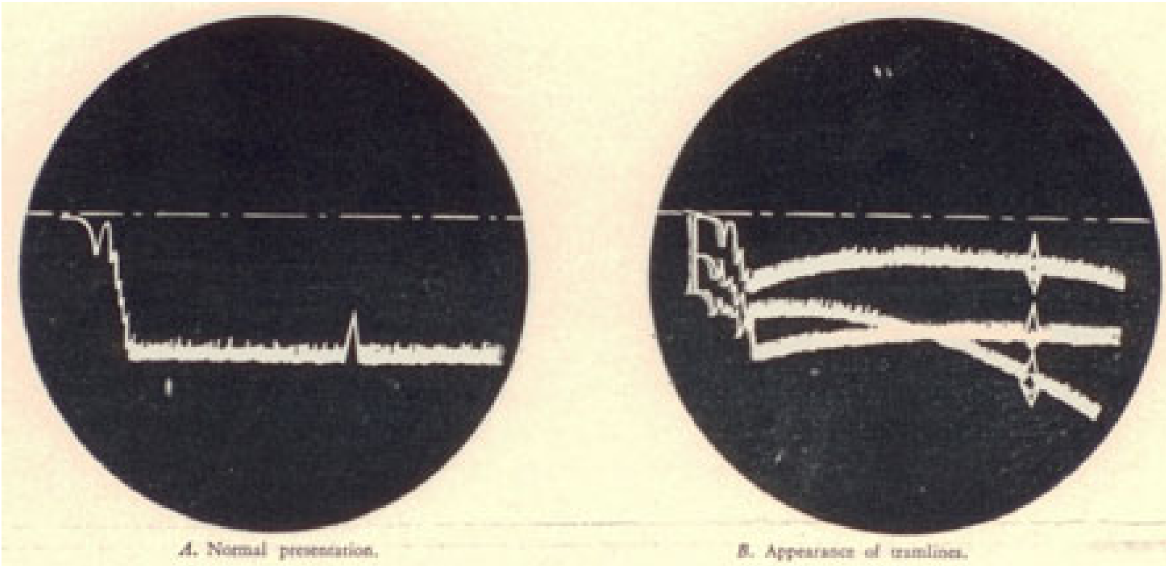

Figure 3-43. Low-frequency jamming.

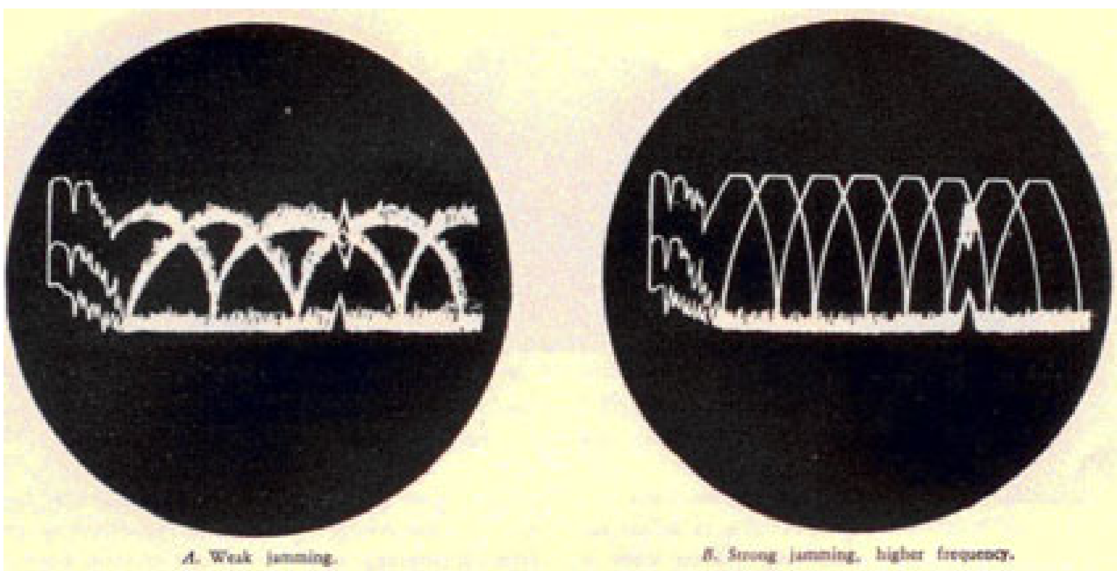

Figure 3-44. Medium-frequency modulated jamming ("basket weave").

that signals will not appear if for any reason the effectiveness of the jamming is suddenly reduced. In figure 3-44 (A) the pip is double-sided, the grass is riding the modulation, and the gain has been adjusted so that saturation is not occurring. B shows a modulation frequency about twice that of A. Saturation is occurring so that the pip does not appear above the jamming pattern, and the normal -receiver grass is not riding on the pattern. This is not dependent upon the modulation frequency, but rather upon the relative strength of the jamming with respect to the echo. The grass could ride on either modulation pattern. If the jamming were not synchronized, it would probably be difficult to see much difference between these two modulating frequencies.

High-frequency amplitude-modulated CW. The pattern obtained from this type of jamming is of the vertical type described under medium frequency and cannot readily be distinguished from it when the jamming is non-synchronous. The echo will have more of the appearance of riding on top if saturation is not occurring, and the lines of shading will be closer together.

Frequency-modulated CW jamming. Frequency-modulated jamming is not distinguishable from amplitude-modulated types except in the special cases of

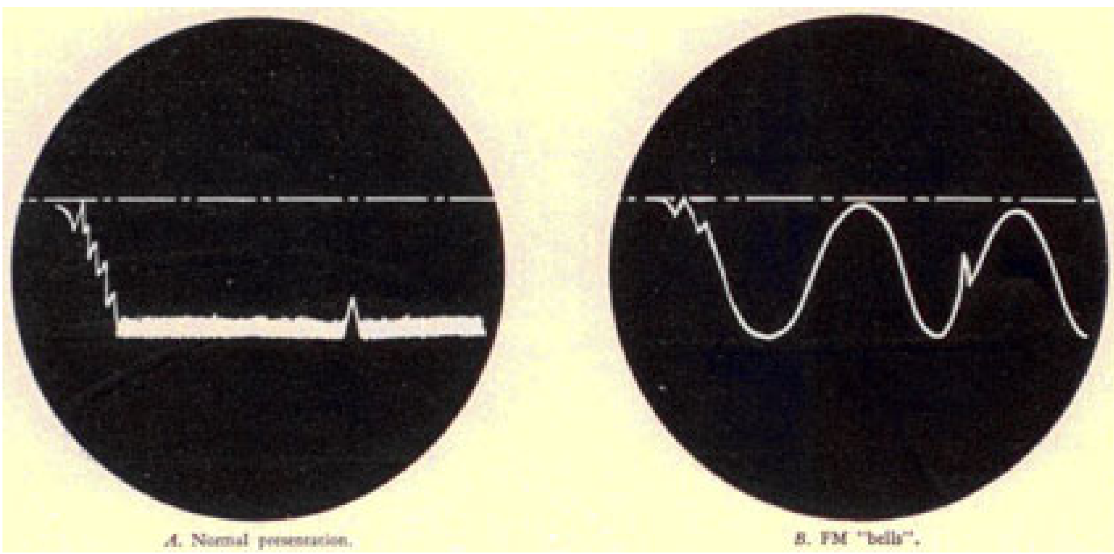

Figure 3-45. Low-frequency, wide-band FM jamming.

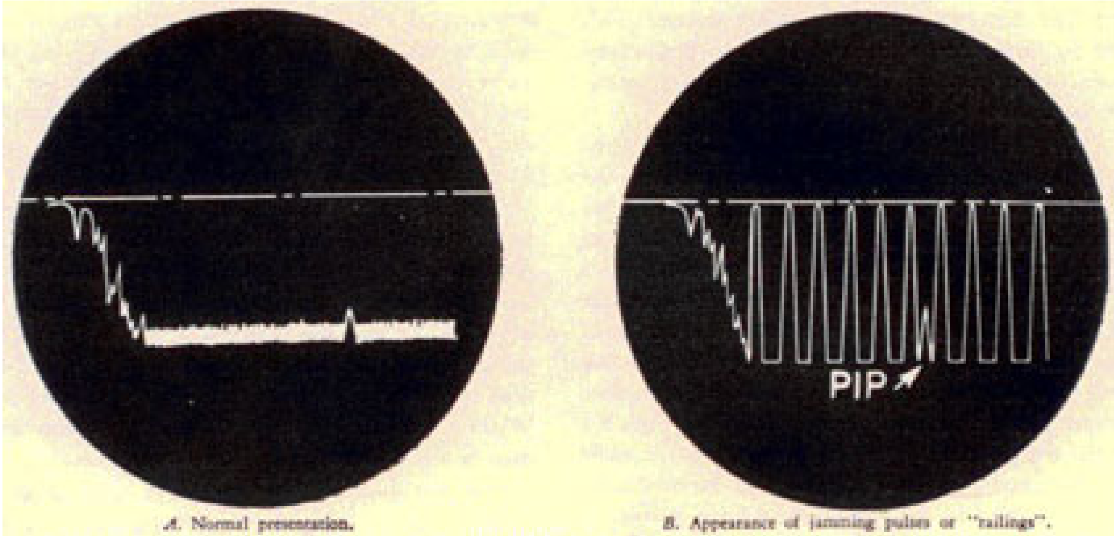

Figure 3-46. Pulse jamming.

low-frequency, wide-band, FM. This produces "cobs" or "bells", on an A-scope screen. These can be fairly confusing if they are moving across the screen at a slow rate. However, an echo pip remains visible as a break in the trace, or by riding the bells.

Pulse jamming. Pulsed jamming transmissions are usually sent out at many times the pulse repetition rate of our radars, so as to cause a number of high vertical pips on the screen. These pips are usually wider than echoes, move together, and are evenly spaced. They may look like a picket fence, or a fine tooth comb, the indications becoming closer together as the jamming pulse rate is increased. The name "railings" has been given to this type of jamming.

It is possible to see echoes through railings that are moving across the screen rapidly, as they do when not synchronized to the repetition rate of the radar. The effect is similar to looking through a picket fence white traveling past it. If the jamming is partially or entirely synchronized, the pattern shows little or no motion, and echoes are harder to, identify but can be found on the baseline and possibly on top of the jamming signal. Railings should not seriously interfere with radar operation, unless they overload the receiver completely.

Mixed jamming. Two or more different kinds of jamming may be sent out simultaneously. The A scope will then exhibit the characteristics of each of the particular types. For example, a variety of "German mixture" is made up of a combination of

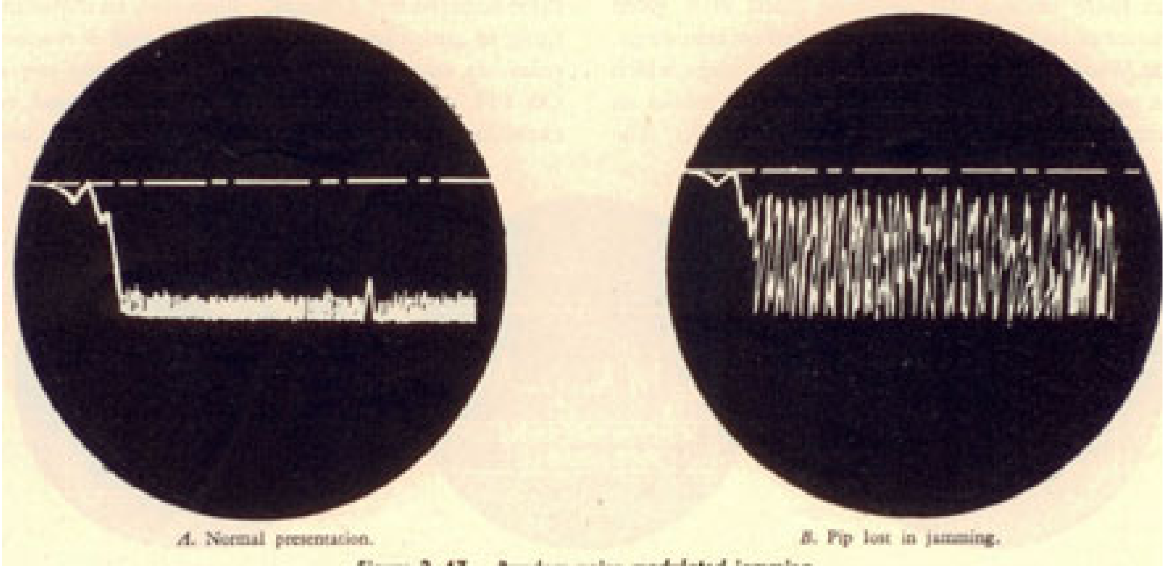

Figure 3-47. Random-noise modulated jamming.

low- and high-frequency amplitude-modulated CW. The high-frequency modulation gives a vertical, closely-spaced, and usually blurred presentation higher up on the screen.

Noise jamming. Noise jamming produces abnormally high grass on A scopes without increasing the level of the desired signal. If the height of the grass is several times that of the echo, it is very hard to work through: With the regular patterns produced by other types of electronic jamming, it is usually possible to adjust the radar receiver controls so as to make the target pip produce some irregularity in the picture, which can then be ranged on, but the random nature of noise does not permit this. It is regarded as the most effective type of jamming, and, if sufficiently strong, very little can be done to combat it. However, effective noise modulation is the hardest to obtain technically, and unless it is good it may be as easy to work through as high-frequency modulated signals.

Window jamming.

strips are cut approximately one-half wavelength long with respect to the frequency of the radar they are to be used against. Mixed Window cut to two or more different lengths corresponding to the frequencies of several radar types is sometimes used. The strips may or may not be paper-backed.

The first operational use of Window was in July 1943, when 700 British bombers dropped 2300 tons of bombs and 30 tons of Window in a raid on Hamburg. A lane or corridor 40 miles wide and 80 miles long leading into the target was infected with the material. As a result, bomber losses were much less than experienced on a previous, similar raid where no Window was used. Since then most combatants have used Window in attacks on land and sea forces.

Window dropped by aircraft first appears as a series of pips trailing out from behind the sowing plane. The indications closely resemble those from aircraft, except that Window gives a very rapid beating effect in contrast to the steady rhythmic beat of real aircraft targets. This is because the strips flutter as they drift downward. When a very large amount of Window is

Mechanical jamming by means of Window is now being employed by the enemy to a much greater extent than any kind of electronic jamming. However, this situation is changeable, making it important to learn anti-jamming measures against both general types.

The name Window probably results from the fact that the material originally consisted of squares or oblong pieces of aluminum foil. When this foil was dropped by an airplane, the light reflections looked like those from many windows. It was found later that more efficient use could be made of a given amount of foil by cutting it up into narrow thin strips. The Window now used consists of such strips which are packed together in bundles when carried in an aircraft and which disperse when dropped. The released, the signals saturate a sizeable portion of the range scale. (See between 1 and 2 in figure 3-48 A). The characteristic beating causes minute oscillations or "ripples" in the trace where it is not saturating. Later, individual pips are seen, as in B. These become broader, more ragged, and less like actual targets as time passes. They occupy a greater portion of the trace when the material disperses, but show only a very slow change in range. Window drifts downwind at approximately two thirds of the wind velocity. It falls at about two to three hundred feet a minute. Therefore, an important thing to remember about Window is that i *t remains relatively motionless compared to an airborne target*. On PPI scopes, Window appears as an island or cloud-like mass which gradually spreads out, and

Figure 3-48. Typical Appearance of Window jamming.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

changes range in the direction of the wind. (See figure 3-48 C.)

The length of time Window will remain on our scopes depends on the altitude from which it is released. When dropped from 10,000 feet, it may be troublesome for as long as thirty minutes on air search radars. If dispersed by projectiles at low altitudes to screen shipping, the time is much less.

Other Mechanical Jamming. On frequencies below 200 megacycles and in the microwave region, long streamers of reflecting material are used in preference to short strips. These streamers are usually parachute supported, and are released in the same manner as packages of Window. This material is called Rope and produces a large echo having a lower rate of flutter than Window.

CLASSIFICATION OF DECEPTIVE COUNTERMEASURES

Window as a deceptive device.

One of the most important uses of Window is to decoy or otherwise deceive the opposing force. It will serve this purpose in a number of different ways. One deceptive use of Window is to create false echoes for the purpose of weakening our defense. In this case a few enemy aircraft make a low-altitude approach to escape detection by long range search radar. When within radar range, they climb to higher altitude, drop a considerable quantity of window, and then retreat in the same manner in which they approached. If our operators do not know how to distinguish Window, they will report a large force approaching. Fighters sent out to intercept the

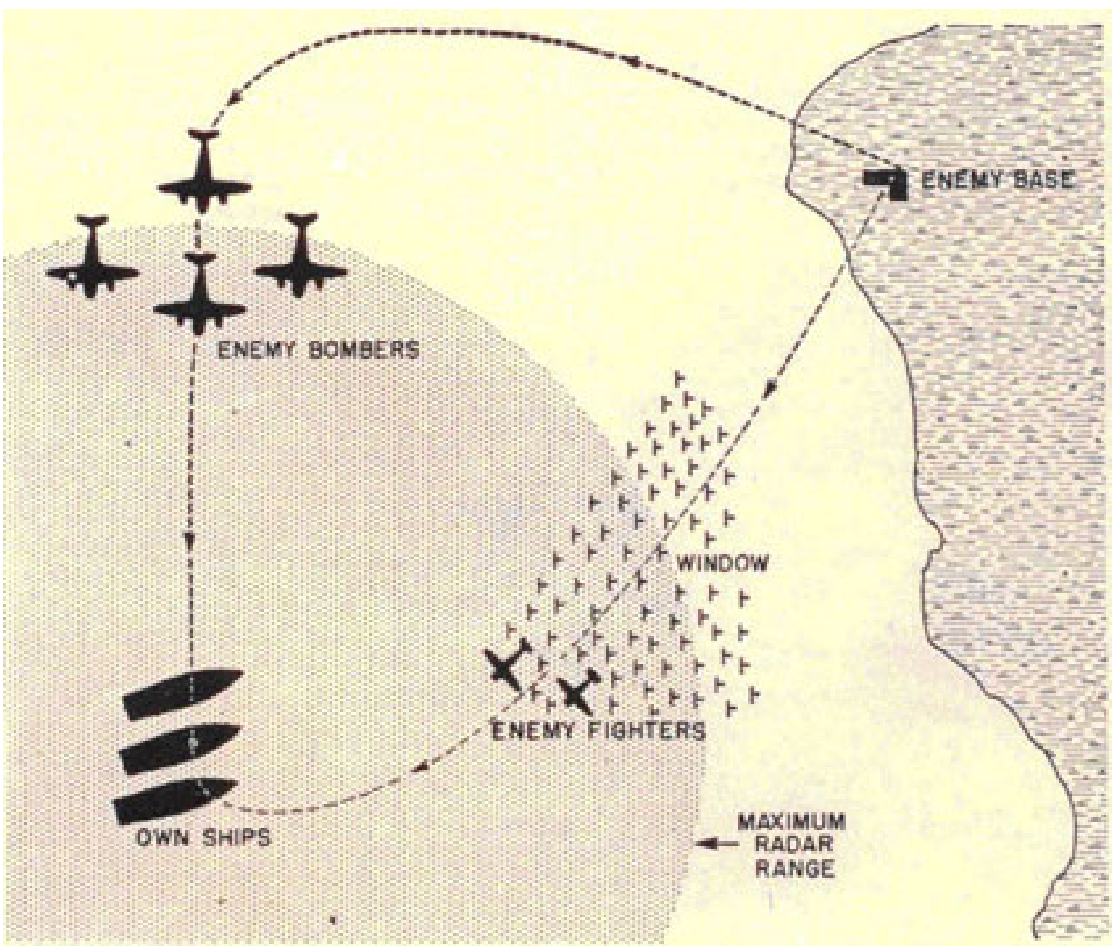

Figure 3-49. Window being used to divert attention from attacking aircraft coming in on a different bearing.

"large bogey" would find nothing. The enemy, on the other hand, having drawn out our fighter protection may be able to send in bombers from another direction while we are looking for him in the Window-infected area. This illustrates the necessity for maintaining a search over 360 degrees.

Another deceptive use of Window is to hide the strength of an attacking air group. During a lengthy operation the enemy may feint a mass attack with only a few aircraft and then suddenly attack with a considerable number of aircraft. In both cases the pip produced may look the same because of the use of Window.

A variation of the above is to use Window to hide changes in course. The Japs have used the material in this way. The aircraft turn while under cover of Window and approach their target from a different bearing. Or, they may appear to be making for one target, but while protected by Window, turn to strike at another.

Window fired by special projectiles may also be used to hide the number and location of surface craft. When sown in this manner, as a countermeasure against surface search or fire control radar, the Window cannot be dispersed from too great an altitude, or it will be above the radar beam. It thus falls in a relatively short time.

Corner reflectors.

Corner reflectors, constructed of three planes at 90 degrees angles to each other, have been used as decoys. These will efficiently reflect a radar pulse back along the same direction from which it came. They may be supported by a balloon or a parachute so as to give an echo like an aircraft, and employed tactically in much the same manner as Window. Other uses include floating them on the surface of the ocean, so as to simulate a surface vessel, or installing them on a small craft to make it appear like a large vessel. Chicken wire may also be spread over a small vessel for this same purpose.

Corner reflectors have been developed for use in life rafts to facilitate finding their location by search planes. The size o these corners is such that they produce good echoes on S-band radars.

Other decoys.

Another type of decoy consists of balloon supported metal strips or wires, which are secured to floats by anchor lines. The streamers are designed to return sizeable echoes to radars of widely different frequencies. The track of the balloon is downwind, at a speed slightly less than wind velocity. The pip indications show less flutter than those from Window, but do have a characteristic beat.

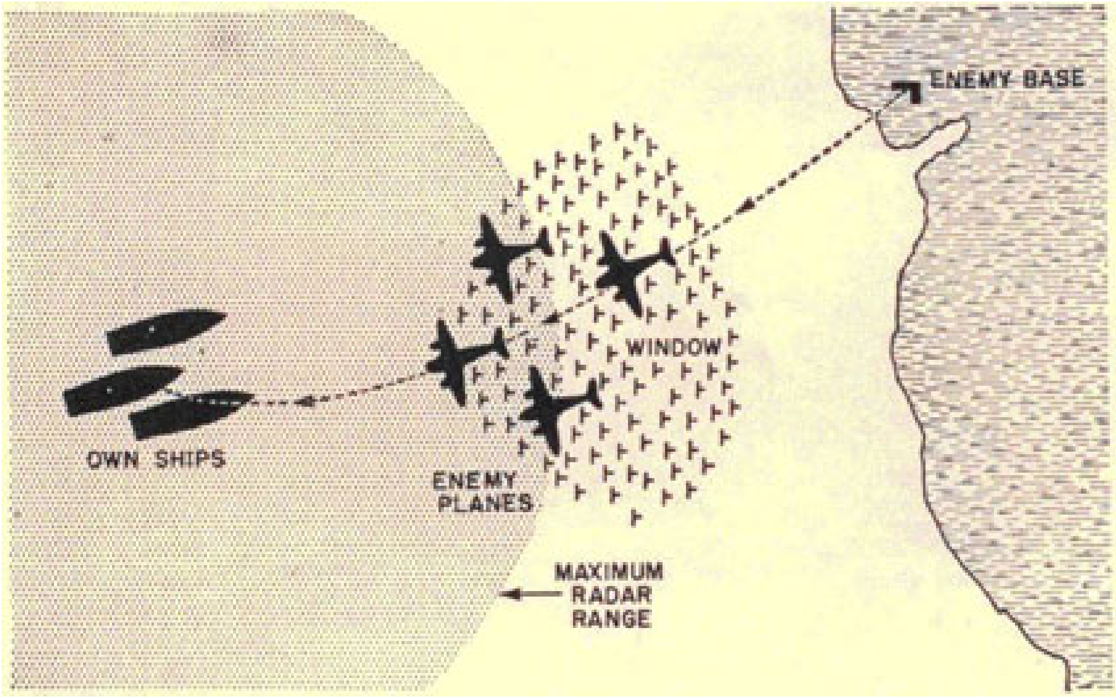

Figure 3-50. Use of Window to hide true strength of on attacking air group.

3-40

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

Balloon and cork-floated decoys have been released by submarines. They might be used to attract attention of attacking aircraft or vessels to allow a submarine time to escape; to divert attention of escorts while a submarine makes an attack on a convoy; to cause an attack to be directed at the decoy, which may conceal a mine; to invite attempts at recovery of the device, which may contain a booby trap; or to cause vessels to open fire, thus disclosing their position to enemy submarines or surface vessels.

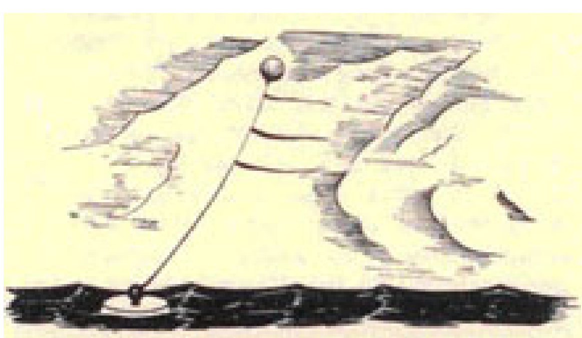

Figure 3-51. Balloon-supported decoy streamers.

Parachute or balloon borne reflectors have been

they reduce the amount of useful information that can be gained from the use of radar. The type of anti-interception measures taken, then, must be decided by the OTC after he has weighed the relative advantages of obtaining all the information of which the radars are capable against the advantages that the enemy might derive from intercepting our signals.

However, there are a few measures than can be employed which will not reduce the effectiveness of our radars too greatly. It is very desirable to keep the antenna in constant rotation partly to make it more difficult for an enemy at any one place to hear the signals for a long enough time to make full use of what he may detect, and partly to deprive him of the knowledge that we have found him by our radars. In some cases, a great deal of useful information can be gained from the radars even though they are operated intermittently, and the long times between the periods of operation may defer the time when the enemy will intercept enough of our signals to use them effectively against us. Some of the new

reported in use by the Japanese. Little is yet known of them as none have been captured. It is reported that they return an echo which is considerably *steadier* than those from aircraft-the opposite case to that of Window. They first appear as if a real target had suddenly divided and become two; but the false signal will stay still, while the aircraft which has dropped it keeps on moving. The balloon type stays on the screen longer than window-one hour or more, according to accounts-and gives a strong pip over a relatively wide band of frequencies. The reflectors have not as yet been released in sufficient quantity to clutter an area completely but they do cause some confusion. The name " *Kite* " is applied to this type of reflector.

The deceptive devices mentioned here are only a few of those possible. It must be realized that the enemy has radar of his own on which to experiment and he is very skilled in devising various sorts of deception. Deception is especially troublesome when used with jamming, and it must be anticipated that more effective countermeasures will be developed by the enemy.

ANTI-INTERCEPTION MEASURES

The measures that an be taken to prevent enemy interception of our radar generally result in interference with the normal operation of the set, and so radars are being fitted with circuits that will assist in intermittent operation, particularly for submarines, and several existing radars are equipped with radiation switches that have "momentary" positions to be used for transmitting intermittently. Radar silence of course deprives the enemy of the chance to intercept the shut-off radars, but it also deprives us of the information that those radars could obtain. Conditions of radar silence will be prescribed by the OTC.

GENERAL ANTI-JAMMING MEASURES

Anti-jamming, often abbreviated AJ, is the art of avoiding enemy jamming or of reducing its effectiveness. The purpose of such measures must be to prevent jamming signals from getting into the radar receiver if that is possible. If this cannot be done, then AJ measures and devices should attempt to prevent the jamming signals from appearing in the output of the receiver, so that the jamming will not be apparent on the indicator screen. In many eases, even this will not be possible, so that AJ techniques must be directed toward creating some sort of discontinuity in the pattern produced by the jamming in order that at least the range of the echo can be determined through the jamming.

Taking direct action.

Bearing information is needed so that the source of jamming may be located and steps taken to destroy

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the jammer. It is easy to find where jamming is coming from by the use of a PPI or B scope. The correct bearing is given by the center of the brightest jammed sector. Turning down the gain helps to distinguish this sector from other areas of the screen which may be illuminated.

If a PPI or B scope is not available, then train the antenna for the highest jamming on the A scope. The gain control should be reduced if the receiver is saturated since variations in the strength of the jamming signal are not apparent in this condition. The provision made in some fire control radars for determining precise bearings enables these sets to indicate very accurately the direction from which jamming comes. For example, tests indicate that the Mark 12 can D/F on jamming with an accuracy of -/+ 5 minutes of arc.

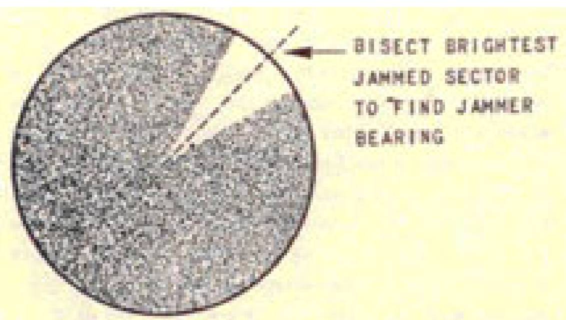

Figure 3-52. Taking bearing on Jammer on a PPI. Only the brightest sector is shown. Jamming will also appear at other bearings due to pick up n side lobes and because of reflection from ports of the ship.

Usually two or more radars at different locations are assigned to take bearings on a jammer. This permits obtaining a "fix" from which range as well as bearing information can be secured. By taking several fixes at different times, it becomes possible to tell in which direction and at what speed the jammer is moving.

A single aircraft can locate a surface vessel jammer by triangulation because the speed at which the plane travels is so much greater than area. Since this plane is causing the trouble, it may be ranged on and action taken to destroy it. However, the presence of Window close to the dropping plane may cause angle errors in lobe switching radars that will handicap anti-aircraft fire control in shooting down this plane.

Employment of radars at different frequencies within one band.

Emission from electronic jammers is confined to a relatively narrow band of frequencies. Jammers cannot effectively blanket more than a few megacycles when tuned to a given frequency, and even then their output falls off sharply on either side of center frequency. Thus, if more than one radar of the same type is to be used, (i.e., in a squadron of ships) it is wise to pretune them to different frequencies within the band, so that some are almost certain to remain effective in the presence of jamming. This measure also has the desirable effect of reducing accidental pulse interference between radars when several vessels are in company. No improvement is obtained against mechanical type jamming such as window, which is broadly resonant within the band it is cut to cover.

Employment of radars on different frequency bands.

An electronic jammer designed for operations against long-wave radars will not interfere with microwave equipments, and vice versa. This indicates the importance of using radars of widely different frequencies at the same time.

Probably the most desirable situation is one in which several radars are used on many different frequency bands, with the frequency of all sets that

that of the ship that the latter may be considered to be stationary. The enemy location is determined by turning say, 300, and then flying a straight course at a constant speed, calling out to the navigator when the jammer relative bearing is exactly 60 degrees and 90 degrees. When there is relative motion between your ship and the jammer, a similar process can be used. For instance a land-based jammer could be located by a single ship.

When Window is being sown by aircraft, the sowing aircraft must be at times ahead of the infected

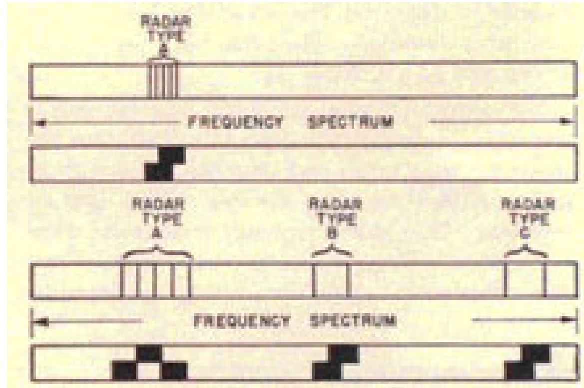

Figure 3-53. Shows the desirability of operating radars widely separated in frequency in each bond, and of using several types to cover different frequency bonds. Block areas indicate frequency coverage of individual jammers.

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operate on a particular band spread as widely as possible within that band. Figure 3-53 shows something of what the enemy is up against under this condition. Note that in. the top picture the enemy needs only two jammers to jam all our radars, and that even with these two, the radars in the middle are jammed by both jammers t once. In the lower picture, however, with three types of radar and as wide a frequency spread as possible between equipments in each type, the minimum number of jammers needed is one per radar, and, very likely, three different types of jammers. With this prospect confronting him, the enemy might decide that the effort necessary would not justify the results. In any event, he could not economically jam as intensely in the bottom case as in the top one. Moreover, with several types of radar you sharply decrease your chances of being jammed, for each type is vulnerable in different degrees to each kind of jamming.

OPERATIONAL ANTI-JAMMING TECHNIQUES

screening, so that as the targets approach, you will at some time be able to see them through the jamming, *but only if the radar is in operation*. However, even if you can do nothing with the jammed indicator, at least you are immobilizing the jammer, and perhaps keeping him from jamming another radar on a slightly different frequency. Continuing operation may indicate to the enemy that his jamming is ineffective, which may discourage him from further attempts.

Do not forget to search continuously through 360 degrees unless this duty has been assigned to other radars and you have been specifically instructed to confine your search to a designated sector.

Report jamming.

As complete information as possible on jamming signals should always be reported immediately to CIC. Report *presence*, *bearing*, *and nature of the jamming* , and state whether it is possible to read through it or not. The tact that jamming is being employed may indicate that important enemy action

Expect jamming.

Be prepared! Tests indicate that an experienced operator, after applying elementary AJ techniques can detect targets through several times the transmitted power required to jam a novice. The enemy has achieved complete success if the radar operator thinks his equipment is at fault when jamming is received and shuts down.

Recognize jamming.

Certain types of interference cause patterns to appear on radar scopes which are very similar to those caused by deliberate jamming. It is very important that the operator be able to recognize interference when it appears, in order to avoid giving false information about what he may otherwise believe to be a jamming attack.

Continue to operate.

Keep operating your radar equipment even if the jamming signals are extremely effective. The effectiveness of jamming will vary as the disposition of the force changes, and if you are persistent enough, some information may be obtained. For example, the jammer antenna may move for a short time into a null in a radar antenna pattern, perhaps allowing the targets to be seen clearly for long enough for you to determine sufficient data to help in their destruction. Remember, too, that there is a minimum range of self

is under way. Reporting the bearing of jamming permits direct action to be taken to destroy the jammer-the best AJ measure of all. Lastly, if the nature of the interfering signals is made known, more effective AJ devices can be perfected.

Figure 3-54. Reporting Jamming. "Bearing zero seven nine-range two-O double-O. Many fuzzy targets-looks like Window. Targets are stationary."

Keep radar operating at peak efficiency.

Unless the radar is carefully maintained, its overall performance will decrease over a period of time. If the output power falls off, the set will be easier to jam since there will be less echo power to compete

RADAR OPERATOR'S MANUAL

with the jamming signal at the receiver input. Therefore, check the level of performance of the set often, and call the technician whenever a decrease in the efficiency is noticed.

AJ TECHNIQUES FOR USE AGAINST ELECTRONIC JAMMING

Training the antenna.

This is a good AJ measure with search equipments when the target and the jammer are on slightly different bearings. If the antenna is trained across the target bearing, it should be possible to reach a point where the edge of the major antenna lobe receives the desired signal, while only low intensity signals are received from the jammer. Attempting to operate in this way must never be allowed to interfere with all-around search, for the enemy may be attempting to jam the radar simply to attract attention in a direction away from the direction from which he plans to attack.

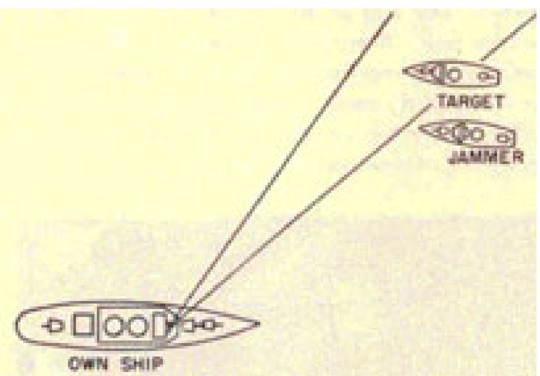


Figure 3-55. Training the antenna so as to pick up the target but not the jammer.

Use of indicator controls.

Examine the A-scope pattern carefully while adjusting the various controls. Remember that electronic jamming signals ordinarily move across the screen, whereas the echo pip remains relatively stationary. This allows the echo to build up in intensity relative to the jamming on successive sweeps, and it provides the best chance you have of finding the target. Therefore, change the pulse repetition rate, if possible, to get the jamming pattern in motion. Look for small breaks in the baseline, bright streaks in the background of the jamming pattern, and bright pips at saturation level of the indicator. Vary the range scale to change the appearance of the pattern produced by the jamming. Sometimes a particular range scale will produce a pattern that is easy to read through. Often an expanded, or type R, scope simplifies the jamming pattern greatly. If the pattern seems regular, observe any discontinuities or breaks in its makeup; signals can be detected by watching for these indications even though the screen may appear hopelessly jammed at first glance.

Use of receiver controls.

There are some controls on all receivers that are useful in combating jamming. Some receivers have certain anti-jamming features incorporated in their circuits so that they have additional controls not found on more conventional receivers. If any of the controls are displaced from their normal settings in the process of trying to read through jamming, be sure to note the correct settings, since the jamming may suddenly cease, or the antenna may have to be turned away from the jammed sector in order to search over the rest of the area. If the correct settings are noted, the set can be restored to normal operation in a minimum of time. Expect interaction between the controls. Adjustment of one often makes readjustment of the others necessary.

Although not all radars have all the controls listed below, they are grouped together as a means of presenting them simply. Remember that even though your radar may not have some of the controls mentioned, you can still do much against most forms of jamming with the adjustments

normally found on all receivers.

CONTROL	COMMENT
Gain	Probably the most useful. Adjust slowly, trying both reduced and increased settings. There is an optimum setting for each target pip.
Local Oscillator (L.O.) (Receiver Tuning)	Try swinging tuning very slowly in both directions. Pip may decrease in size or become distorted but this does not matter if readability is improved. Unmodulated jamming is easy to tune away from. In addition, there may be holes in the frequency coverage of the jammer you are working against. Care must be taken to note the original and correct setting of the control so that normal operation can be resumed immediately on cessation of jamming.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

CONTROL	COMMENT
AFC Switch (Automatic Frequency Control)	Try both "on" and "off" position. You cannot vary the L. O. tuning with AFC on.
AVC Switch (Automatic Volume Control)	Try both "in" and "out" positions. On receiver used with SC/SK series radars, where a three-position switch is provided, try all three positions starting with position #3.
Rejection Slots	Best against low modulation frequencies, ineffective against noise. If two controls are provided, vary first one and then the other very slowly to improve readability. If no success, return to "out" position.
Video Filters	If several types are available, try each in turn in conjunction with L.O. tuning. These filters introduce a constant range error which should be accounted for on fire control equipments. Also they distort the pip, so do not try to center in notch. Instead, align leading (left) edge of pip with leading edge of notch.
Video Gain	Try different settings while also adjusting the main gain control.
Pulse-Length Selector Switch	Try various positions. Longer pulse lengths are generally better against electronic jamming.

Balanced Video

This control is usually of no use for improving A-scope presentation. It is only advantageous on the PPI, particularly against pulse or railing type jamming. Best operation is secured when the pulses are reasonably square.

AJ TECHNIQUES FOR USE AGAINST WINDOW JAMMING

Observe windward side of Window area.

Since the material may blow away from the targets, the windward side of the jammed area should be watched with particular care. Watch for pips beyond the Window cloud-targets on the same bearing but outside the infected area will be detected as readily as those on totally different bearings from the Window. Search on all bearings as the purpose of the jamming may be to divert attention from an attack coming from another bearing.

Look for holes in the Window cloud.

The enemy plane may have had to take evasive action with the result that the Window is not properly sown, and holes may exist through which targets

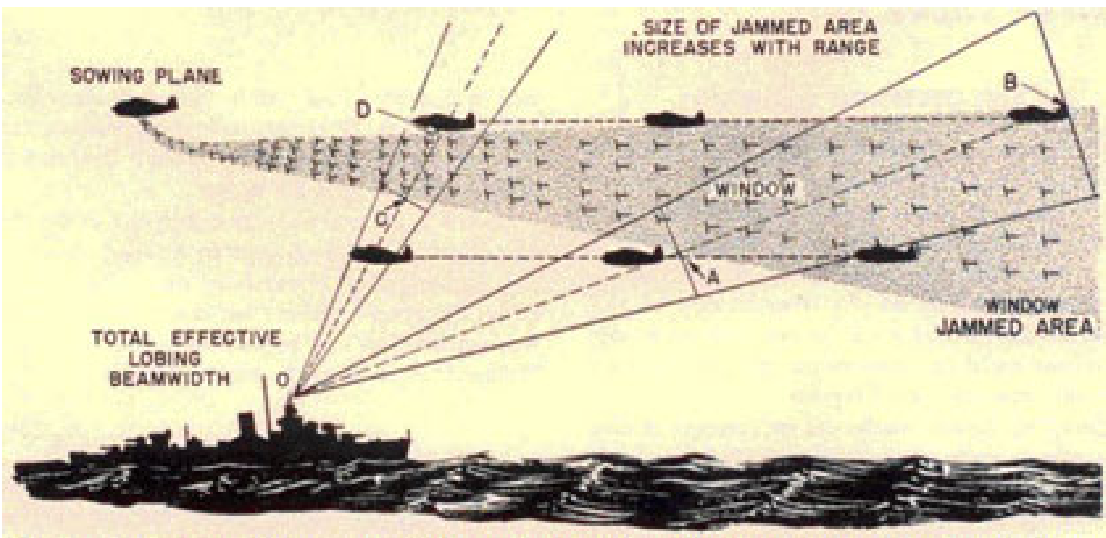


Figure 3-56. Relation between Window dispersal, jammed area and attacking aircraft.

RADAR OPERATOR'S MANUAL

can be spotted. Also, if your radar has a short pulse length and a narrow antenna beam, the Window may not have been sown closely enough to interfere with detection of targets because of the superior range and bearing resolution available in your set.

Continue to try to track targets through the Window.

After some experience it may be possible to track aircraft targets through Window by noting the difference between the violent beating of the Window echoes and that of the target. If it has been possible to track the target for a time before the Window is sown, some estimate of the targets speed may have been obtained. By using this information, it may be possible to pick up the target as it comes out of the Window area by moving the range step through the jammed area at the estimated rate of speed of the target. An expanded presentation, such as the R scope, is especially helpful in assisting the tracking of targets through Window because it permits full use to be made of the resolution inherent in the radar. Any holes in the Window cloud will be much more noticeable on the expanded scale than on any other range scale.

Window jamming can be worked through more easily at short ranges than at long. In figure 3-56 long range Window contacts jam a larger area in the range scope than Window at short range because of the lower angle penetration of the radar emissions into the Window. For example, if the radar antenna is elevated to a higher position angle, the radar will be jammed between ranges OC and OD instead of between OA and OB. Planes flying at a constant altitude may emerge from the jammed zone as the range closes.

Use of receiver controls.

Many of the controls useful against electronic jamming will be entirely ineffective against mechanical jamming. Only these controls listed below have some possibilities.

CONTROL	COMMENT
Gain	This is one of the most effective controls. Try changing the position both up and down to determine the optimum setting and to prevent saturation.
Pulse-Length Selector Switch	Use the shortest possible pulse length. This will improve the range resolution of the radar.
IAVC and FTC (Instantaneous Automatic Volume Control and Fast Time Constant Coupling)	Both of these special devices, incorporated on the more modem radars, increase the ease of working through Window.

ANTI-DECEPTION MEASURES

If deception is carefully carried out, it will be impossible to reveal the echoes as false within a short period of time. If only a few minutes pass before the deception is detected, it may have served its purpose. Therefore, operators must learn to observe and remember all the characteristics of true echoes in order that they will be able to detect quickly even small variations from normal that may be apparent with some types of deception.

Deceptive devices usually can be revealed as false if a plot is made of their course. If the device is hung from a balloon or a parachute, or is floating free in the air, its motion will always be in the direction of the wind aloft, and the speed will compare reasonably closely with the wind speed, but never exceed it. It is well to realize, however, that the wind speed and direction at 2000 feet may be different from that at the surface.

Since it is difficult to make a deceptive device that can affect all radar frequencies equally, deception may sometimes be revealed by comparison of the echoes on several radars that operate on different frequencies. This may be done quickly on a repeater PPI by simply turning the selector switch.

ANTI-EVASION MEASURES

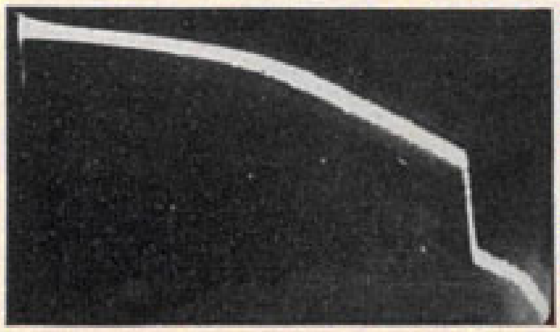
The enemy can resort to evasive tactics to prevent or postpone radar detection only because he

is aware of the limitations of our radars. Since it is quite apparent that the Jap knows how to take advantage of these shortcomings, there is little that an individual operator can do to combat evasion, except to practice faithfully in order to become so expert that it will be very difficult for the enemy plane to get out of the radar beam. If the limitations of our present radars, such as the poor coverage against low-flying planes or the inability to indicate altitude accurately and continuously, are overcome in new radars, it will then be nearly impossible for enemy planes to avoid detection or to confuse the operators by radical maneuvering. However, about the only means we have of combating evasion at present is to attempt to extend the coverage of our radars by deploying picket ships as far as 50 miles away from the main force, and establishing extensive coordination among all the CICs in the force.

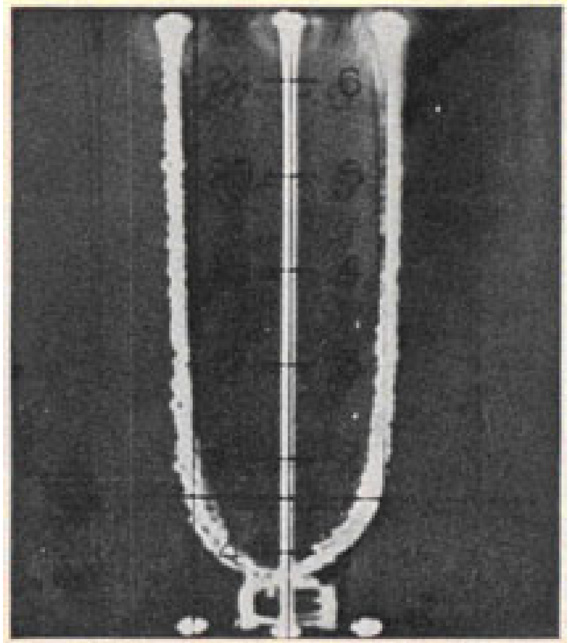
PHOTOGRAPHS OF JAMMING ON RADAR INDICATORS

This section illustrates scope presentations in the presence of various types of jamming that have been employed. Electronic jamming on type A scopes is shown in Figures 3-57 to 3-72, on type PPI scopes in Figures 3-73 to 3-81, and Window jamming on both type A and PPI scopes in Figures 3-82 to 3-85. The captions of each figure give appropriate AJ measures for the type of jamming illustrated, in order of preference. Unless otherwise mentioned, the sweep for A-scope presentations corresponds to a 40-mile range scale.

It should be realized that, while the photographs represent as closely as possible commonly encountered conditions, the actual pattern is usually in motion. For this reason, the camera cannot duplicate what the eye sees.



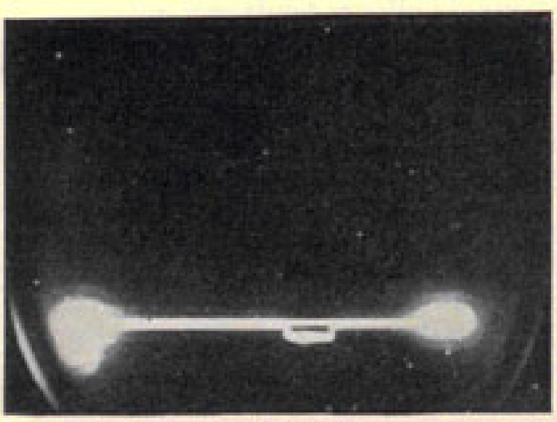
A. Air search radar *A* scope. The trace is wiped clean and is distorted by the overloading of the receiver.



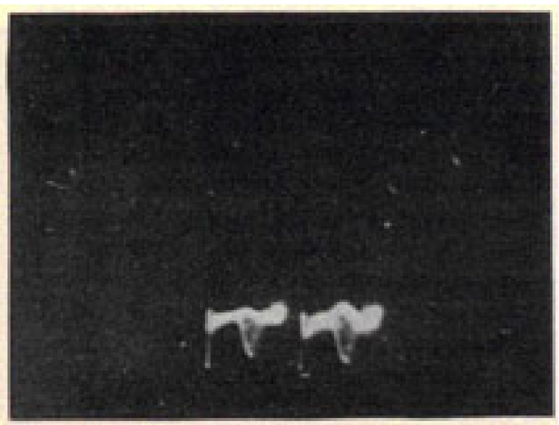
B. ASB type L scope. Note characteristics gap between traces and baseline.

AJ-Reduce gain slowly to find optimum setting. Detune L.O. Rejection slots effective.

Figure 3-57. Unmodulated CW Jamming.



Range scope

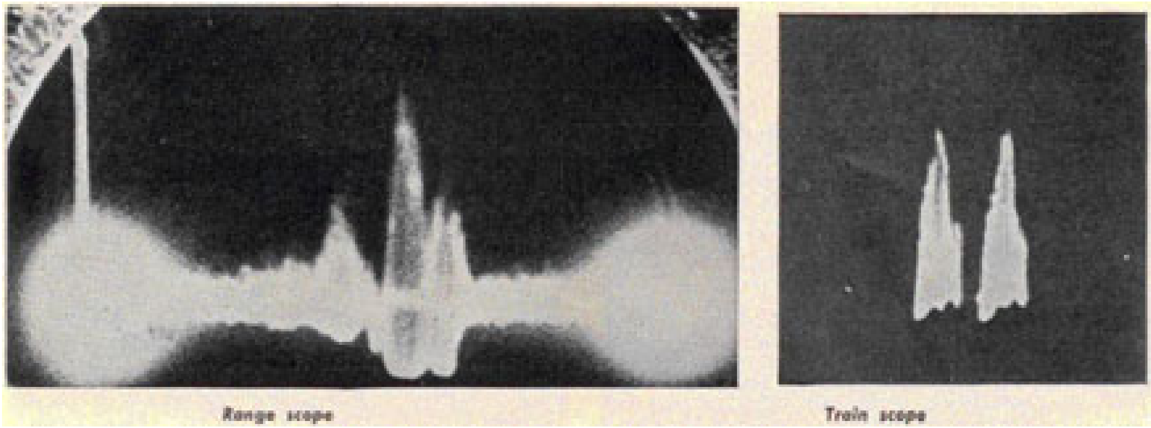


Train scope

Strong jamming is overloading receiver and almost wiping trace clean. Echo is strong enough to produce inverted pips which are visible on Train and Elevation scopes due to fast sweep.

AJ-Adjust gain control to optimum setting. Try video filters. Try L.O. detuning. Turn off lobe switching if range and only approximate bearing ore desired.

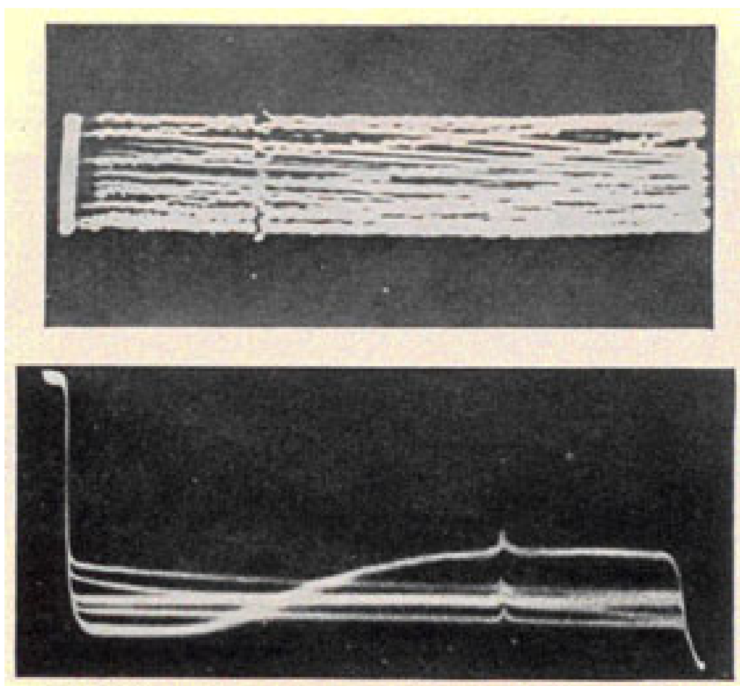
Figure 3-58. Unmodulated CW Jamming (Mark 4 radar).



Moderate jamming with gain control at optimum setting. Echoes are double-sided, filled-in, and fuzzy Bearing accuracy is probably impaired.

Figure 3-59. Unmodulated CW Jamming (Mark 4 radar).

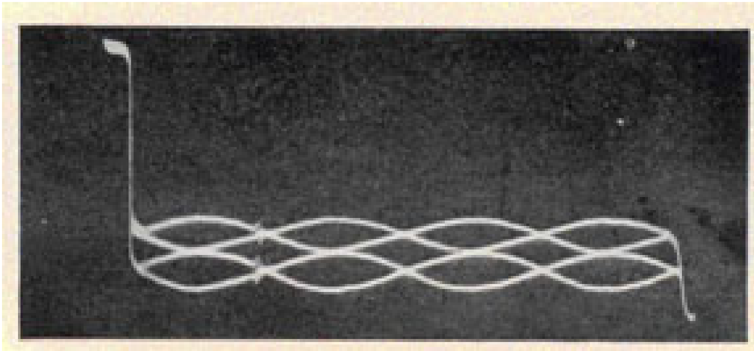
DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES



This type of jamming is known as "tramlines." Less than one cycle of the jamming modulation appears on each trace. Echo present on each trace.

AJ-Adjust gain to optimum setting. Try detuning L.O. Try rejection slots. Use video filters (FTC is a form of video fitter). Try various selections of AVC time constant, or use IAVC.

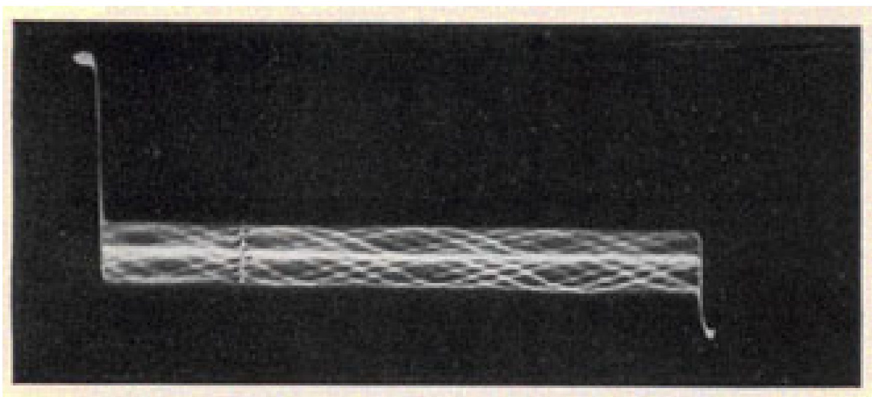
Figure 3-60. Low Frequency AM Jamming.



An example of "Basket weave" Jamming. The jamming is synchronous, and has a modulating frequency higher than that in Figure 3-60. Approximately two cycles of the modulation are appearing on each trace.

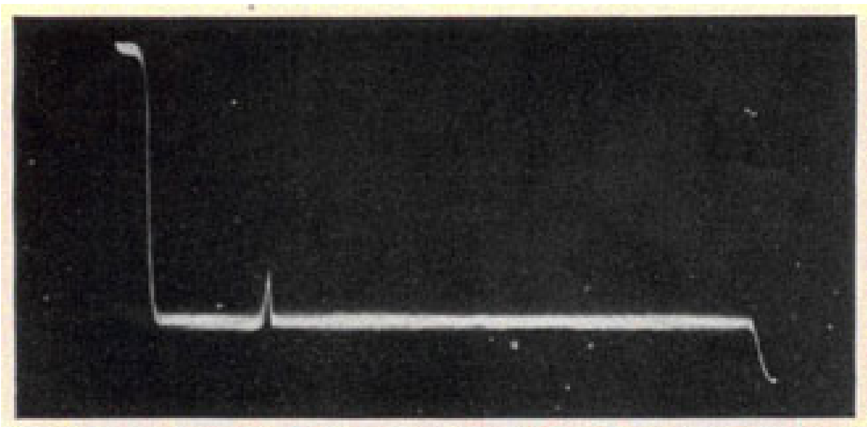
AJ-Adjust gain to optimum setting. Try detuning L.O. Try rejection slots. Use video filters or FTC. Use IAVC or try various settings of AVC time constant.

Figure 3-61. Low Frequency AM Jamming.



A. A non-synchronous, "basketweave" type of jamming. Pip shows as break in each trace.

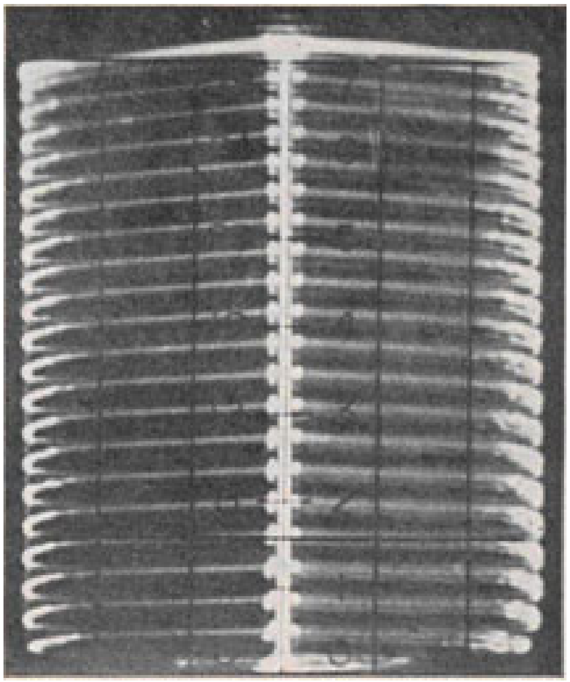
AJ-Adjust gain control to optimum setting. Try detuning L.O. Try rejection slots. Use video filters or FTC. Try various selections of AVC time constant, or use IAVC.



B. Same condition as in A, except with rejection slot set to carrier frequency of jammer. Jamming modulation has been practically removed, but still shows up as a thickening of the baseline.

Figure 3-62. Low Frequency AM Jamming.

Figure 3-63. Medium-Frequency AM Jamming (ASB radar).



An example of semi-synchronous jamming modulation. Because the baseline on the ASB is vertical (type L presentation), low-frequency tramlines appear vertical and medium- or high-frequency modulations give a horizontal pattern.

AJ-Adjust gain control to optimum setting. Try detuning L.O. Try rejection slots.

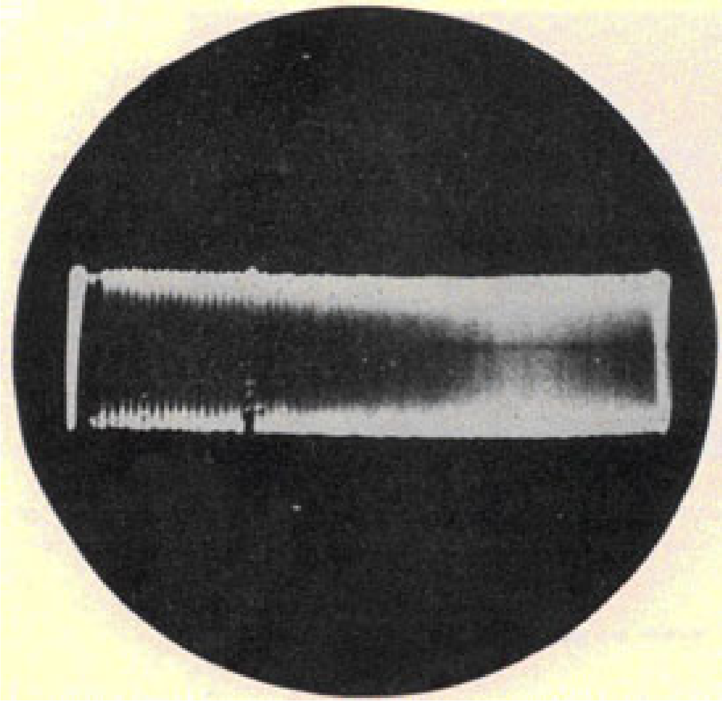
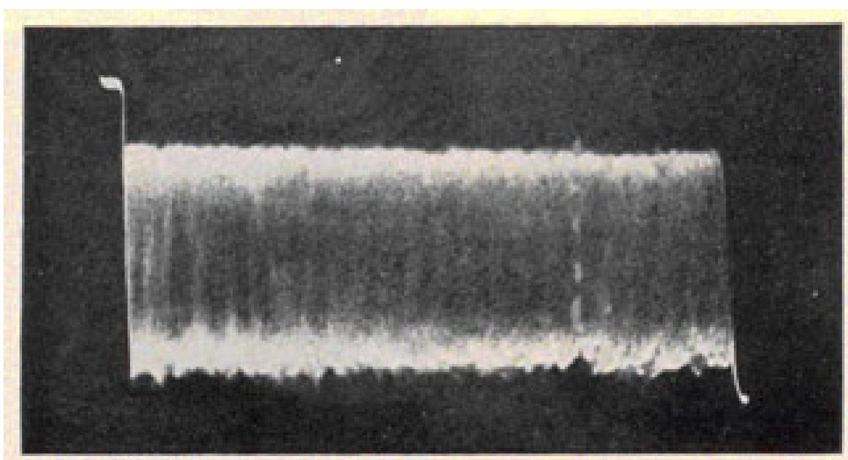


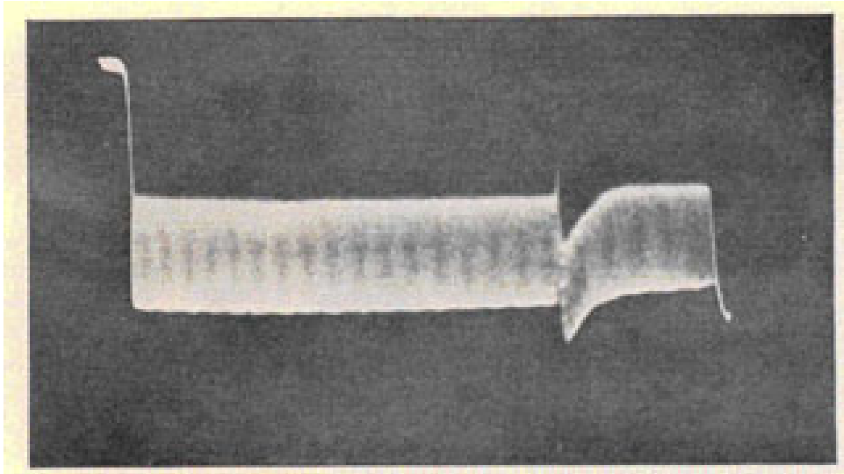
Figure 3-64. Medium-Frequency AM Jamming (Army radar).

Jamming modulation is non-synchronous, Modulation on frequency is difficult to determine. Note vertical striations in body of pattern. No AJ devices are being used and gain is set at normal setting. Pip causes break at baseline and runs through jamming pattern, but is difficult to find.

AJ-Adjust gain control to optimum setting. Try detuning L.O. Try rejection slots.

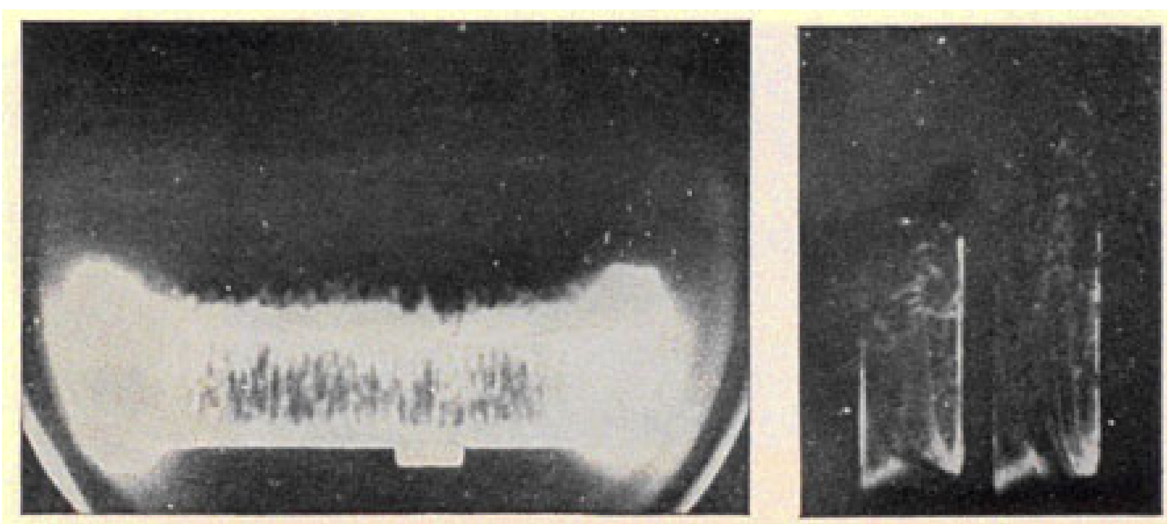


A. Jamming modulation is non-synchronous. Striations in body of pattern are less visible than in Figure 3-64, Gain setting is normal. Pip causes break in baseline, and runs through the jamming pattern, but is almost invisible.



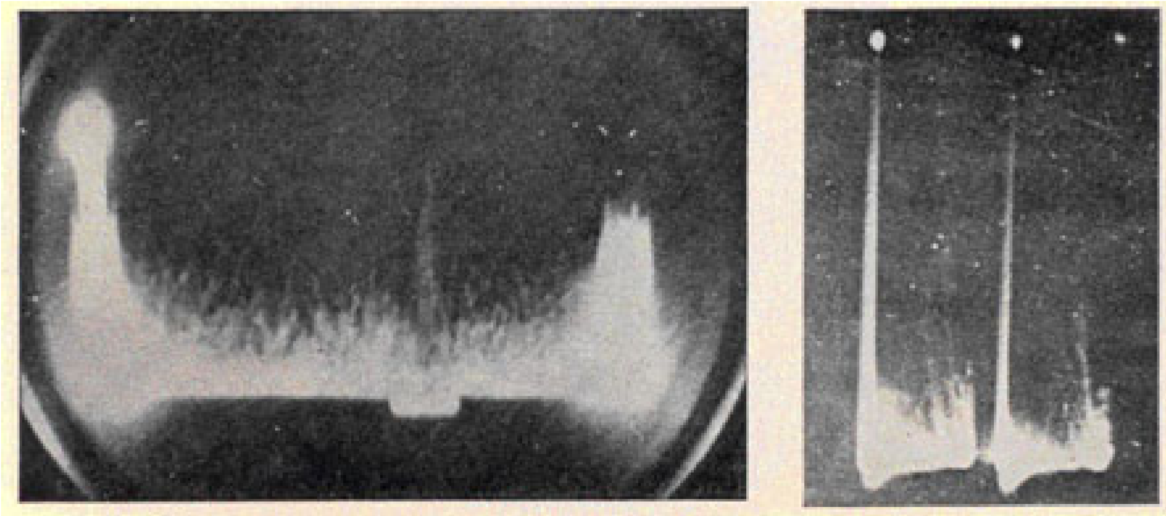
B. Same condition as in A, except gain control has been set to optimum setting. Pip now produces marked irregularity in pattern. Rejection slot also being used, but it is not completely effective because of presence of small amount of frequency modulation.

Figure 3-65. Medium or High-Frequency AM Jamming.



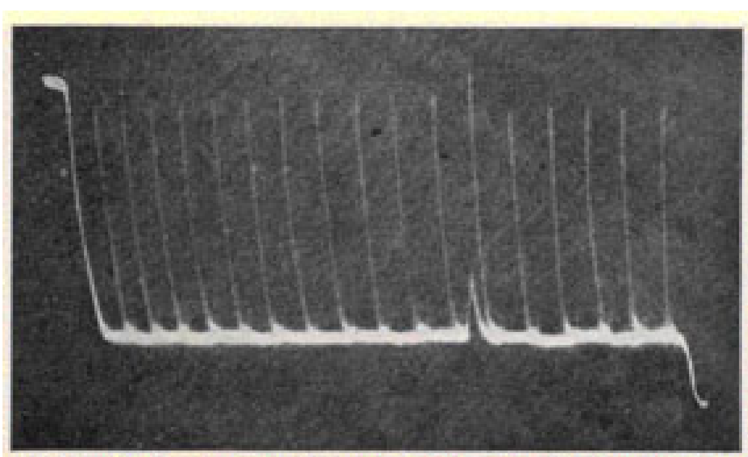
A. Moderate jamming. Modulating frequency of jammer is about 200 kilocycles per second. Possible to obtain range, but train and elevation pips are too fuzzy to be used.

AJ-Adjust gain control to optimum setting. Try video filters, starting at lowest number. Try detuning L.O.

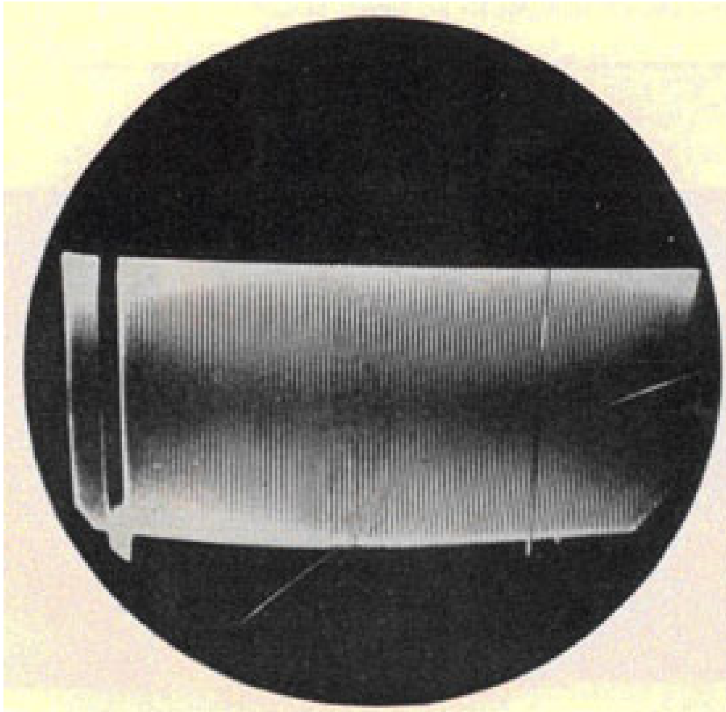


B. Same condition as in A, except that AJ measures have been applied. Only gain control adjustment was necessary in this case. When weak jamming is encountered. video filters should be used with caution. Angular errors result unless jammer is definitely known to be on target. Do not forget to "spot" the range when filters are used. On Train and Elevation scopes, do not match total heights, but rather the height of the pip above jamming pattern.

Figure 3-66. High-Frequency AM Jamming (Mark 4 radar).



A. Synchronized jamming pattern, sometimes called "railings".



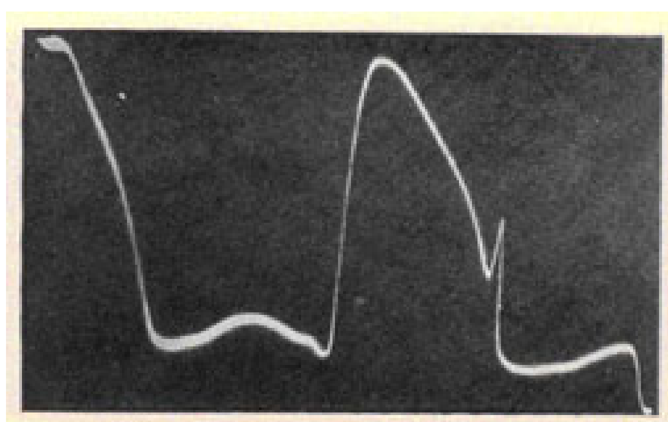
B. Similar to A, but on Army radar. Jamming has higher repetition rate or longer range scale is in use. Non-synchronous pulse jamming of high PRR is hard to distinguish from high-frequency AM jamming.

AJ-Adjust gain control for optimum setting. Change PRR if possible, to make jamming move rapidly across scope. Try balanced video to improve PPI'S readability. Try detuning L.O.

Figure 3-67. Pulse Jamming.

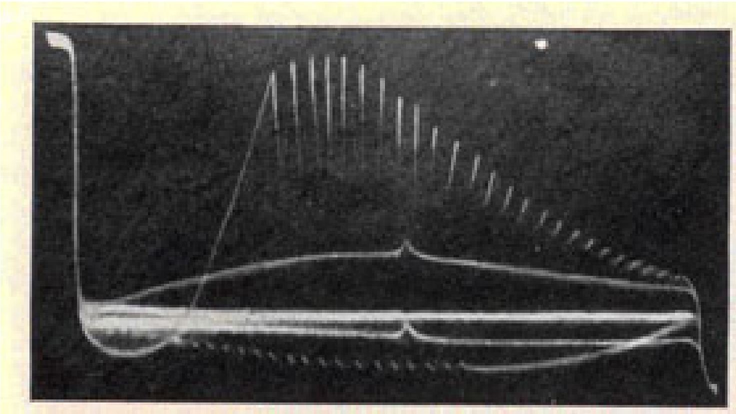
DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

Figure 3-68. Low-frequency FM Jamming.



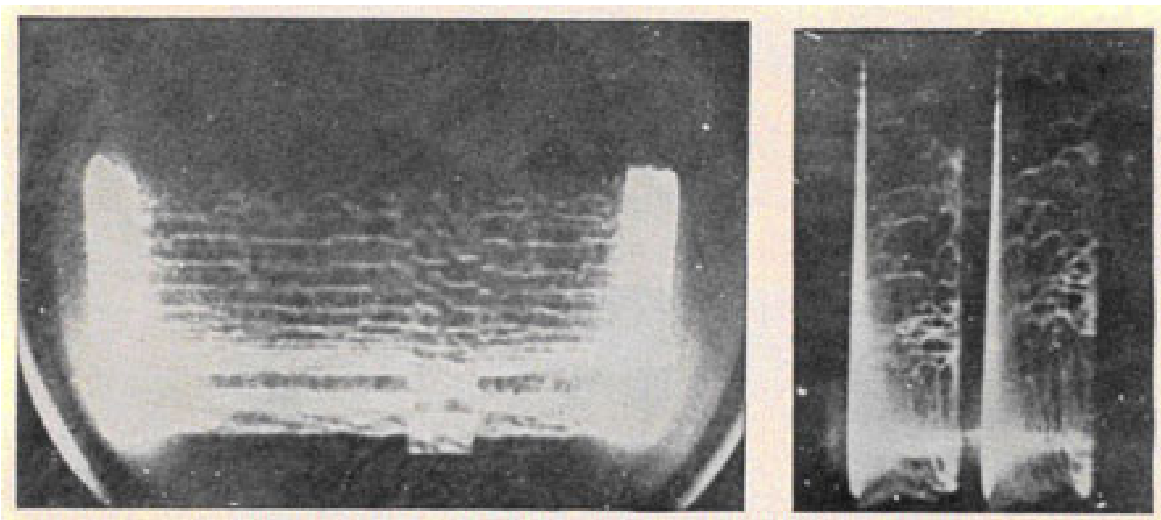
Synchronized presentation commonly called "bells" or "cobs" Pip rides on top of pattern. Other types of FM jamming produce patterns similar to AM, and are no harder to work through.

AJ-Change PRR to obtain rapid movement of bells. Reduce gain if pattern is saturating.



A. A combination of 240 cycle and 10 kilocycle jamming modulations. The lower frequency causes the tramlines, and the higher frequency the vertical indications.

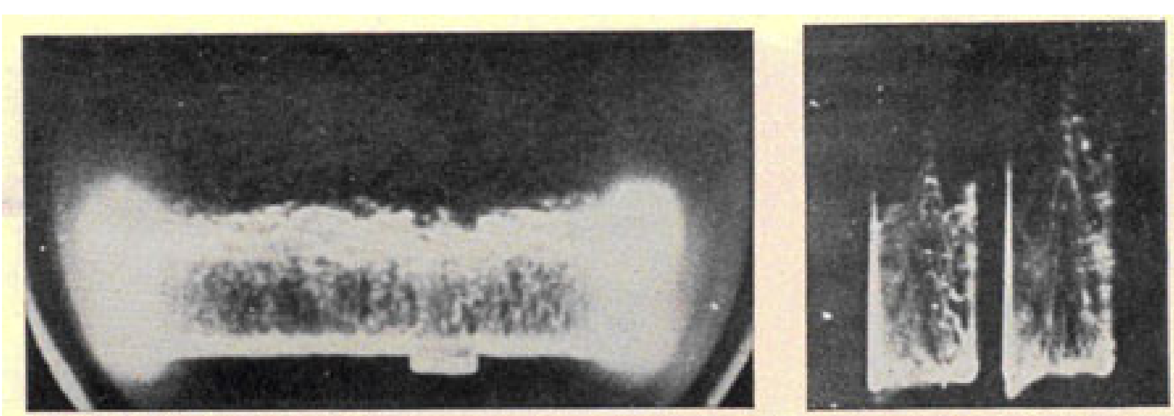
AJ-Gain control. L.O. detuning. Rejection slots. Video filters or FTC. Short time constant on AVC or IAVC.



B. Jamming pattern called "German Mixture" on Mark 4. Made up of 50 cycle and 100 kilocycle jamming modulations. In presence of jamming, Mark 4 often gives appearance of mixed jamming when lobing is used, because pattern is "chopped up" at lobing rate.

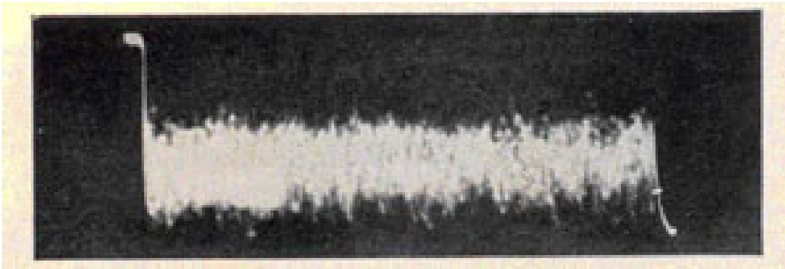
AJ-Adjust receiver gain. Try video filters. Try detuning L.O.

Figure 3-69. Mixed AM Jamming.



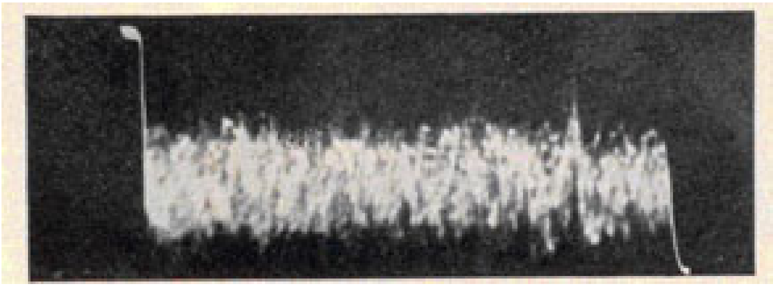
Moderate jamming-jam-to-signal ratio slightly less than effective value. Gain control was adjusted for optimum pattern. On train and Elevation scopes, do not match total heights, but rather height of pip above jamming pattern.

Figure 3-70. Random Noise Jamming (Mark 4 radar).



A. Weak pip lost in grass produced by jamming. A difficult type of jamming to work through, but keep trying. Effectiveness of noise jamming depends on the strength of the jamming relative to the echo strength.

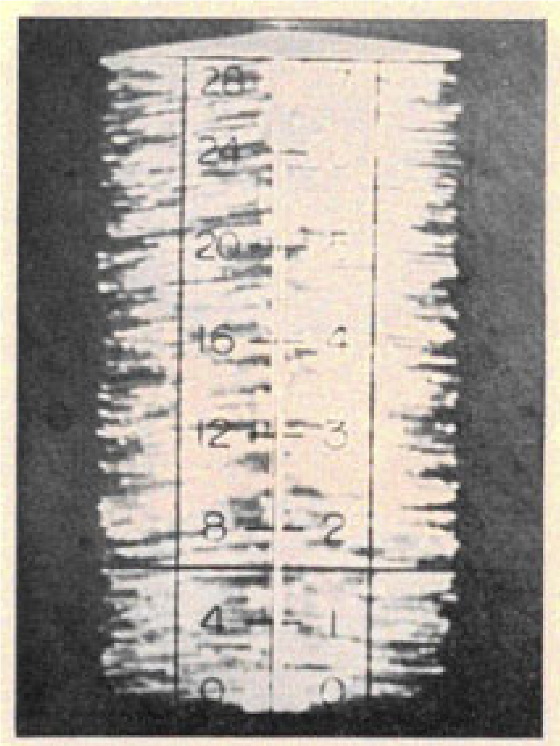
AJ-Adjust gain control to optimum position. Vary L.O. tuning.



B. Jam-to-signal ratio is below effective value. Either echo is stronger or jamming is weaker. Gain control has been adjusted to optimum value.

Figure 3-71. Random Noise Jamming.

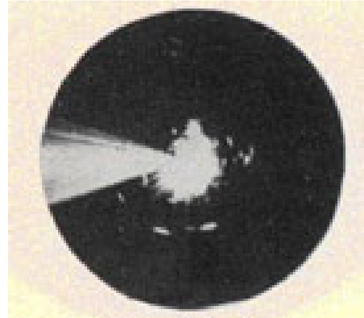
DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES



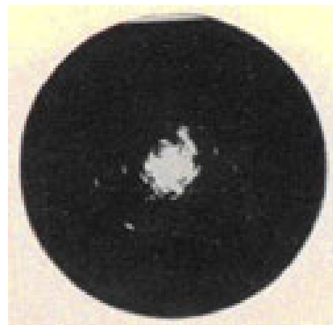
Strong jamming of almost saturation level. While this jamming may he practically impossible to work through, change of position with respect to the jammer may reduce the jamming strength to a level where targets could he detected.

AJ-Adjust gain control to optimum setting. Try detuning L.O. Try video filters.

Figure 3-72. Random-Noise Modulated Jamming (ASB Radar).



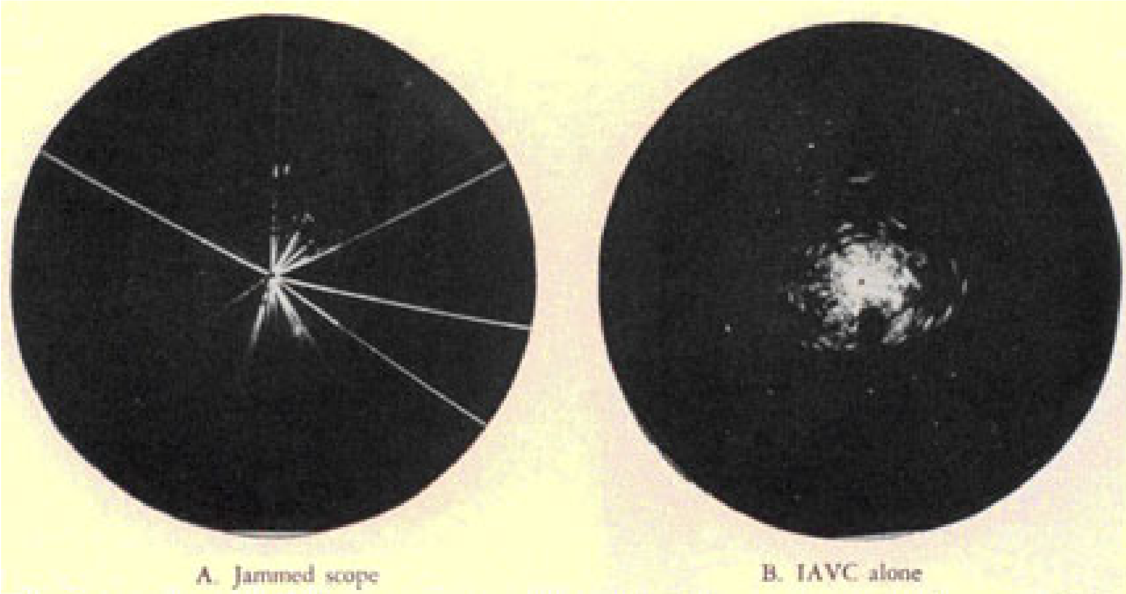
A. Moderate strength jamming. Striations appear at outer edges of jammed sector because of continuous rotation of sweep.

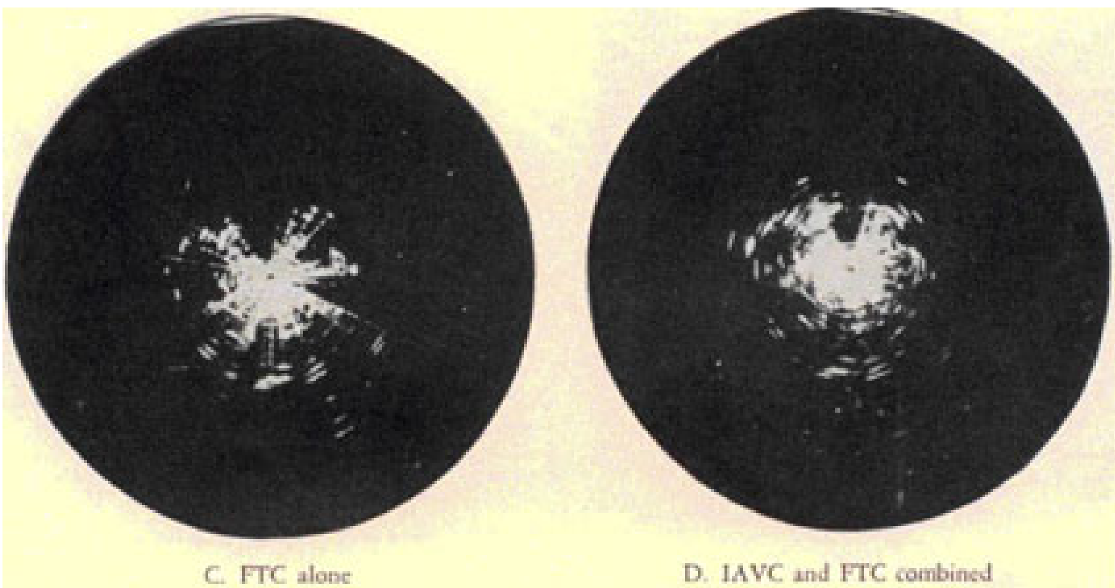


B. Same as in A after applying AJ measures. Gain was reduced (too much in this case) ant the FTC cut in. Slightly higher IF or video gain would restore more of the targets to their normal brilliance.

AJ-Adjust gain to optimum setting. Try rejection slots. Try detuning L.O. Try video filter or FTC.

Figure 3-73. Unmodulated CW Jamming.

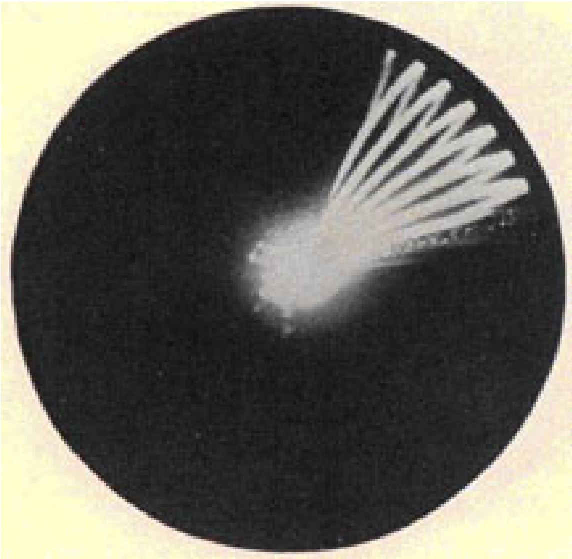




Strong jamming. Very few echoes show in A because the receiver is saturated by the jamming received not only in the main lobe but also in the minor and back lobes. Note the successive improvement as a result of using IAVC, FTC, and in D, a combination of both.

Figure 3-74. Unmodulated CW Jamming.

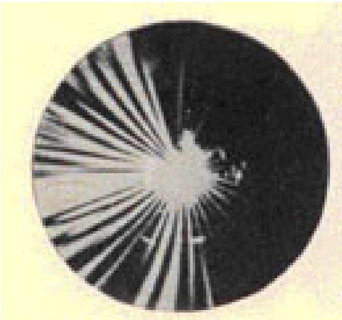
DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES



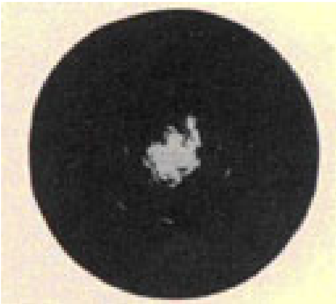
Jamming is synchronous. Low and medium frequency modulations are characterized by radial bands when synchronous or semi-synchronous condition is present. Setting of gain control has been reduced so that side lobes are not visible.

AJ-Try video fitter or FTC. Adjust gain control to optimum setting. Try detuning local oscillator. Try rejection slots.

Figure 3-75. Low-Frequency AM Jamming.



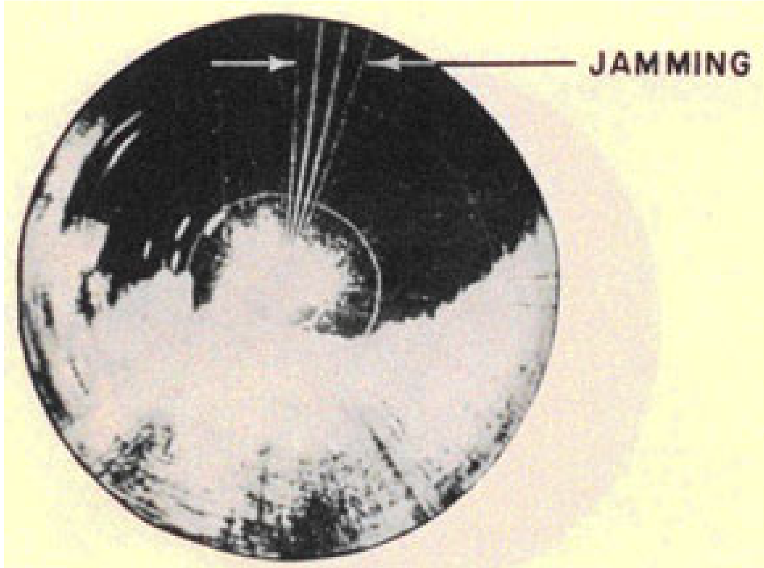
A. Jamming appears over a wide sector because it is quite strong. Note radial bands characteristic of synchronous low-frequency modulated jamming.



B. Same as A after applying AJ measures. FTC was cut in and gain reduced Note improvement in definition in ground clutter area at short range due to use of FTC.

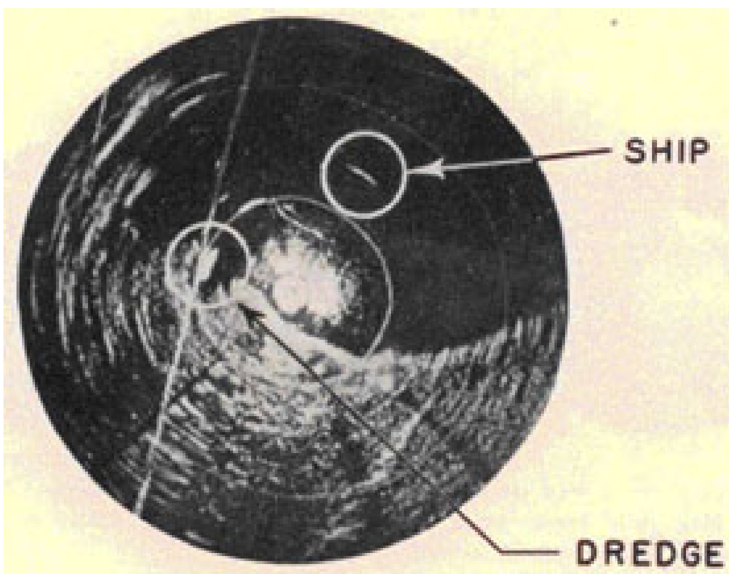
AJ-Try video filters or FTC. Adjust gain to optimum setting. Try detuning L.O.

Figure 3-76. Low-Frequency Sine Wave AM Jamming.



A. Twelve-mile sweep of airborne radar being used. Target is lost in jamming at about 7 miles. Note radial-hand characteristic of jamming.

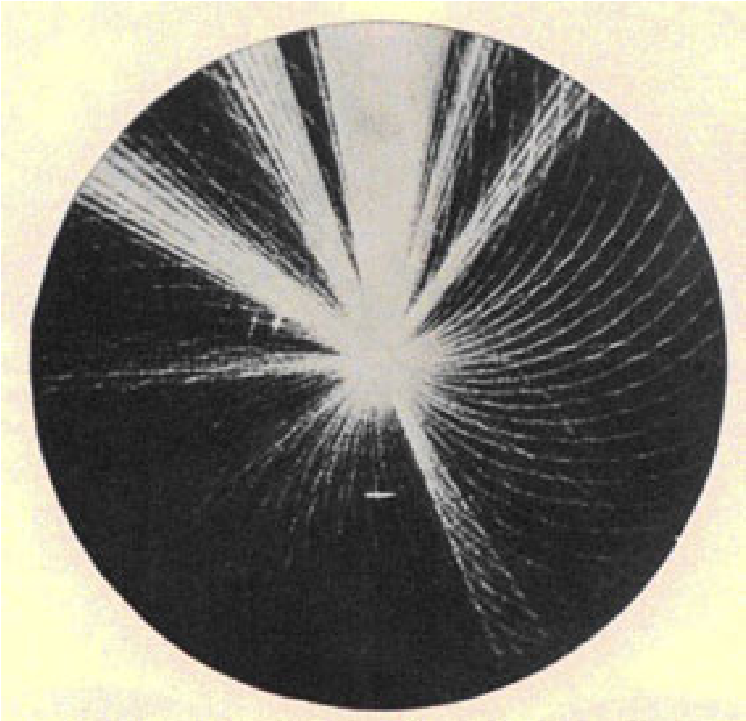
AJ-Try video Alters or FTC. Adjust gain to optimum setting. Try rejection slots. Try detuning L.O.



B. Same as A after applying Al measures. FTC was cut in and gain control was adjusted. FTC has eliminated jamming and considerable clutter. Note ship echo and echo from dredge anchored near shore which were both previously lost.

Figure 3-77. Low-Frequency Sine-Wave AM Jamming.

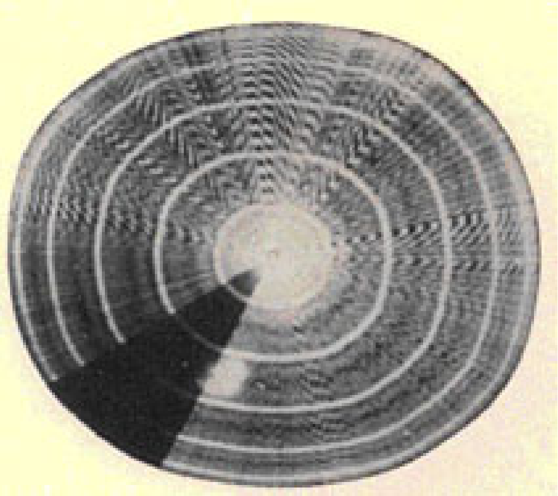
DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES



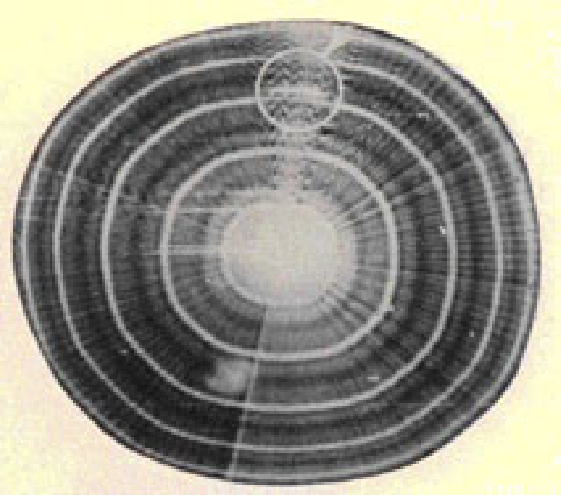
Note that radial hands are closer together than in Figure 3-77 because of higher frequency of modulation. Jamming is stronger and is entering side lobes of radar antenna. Spiral lines are caused by interference from another radar.

AJ-Try video filler or FTC. Adjust gain to optimum setting. Try detuning L.O.

Figure 3-78. Medium-Frequency Sine-Wave AM Jamming.



A. Airborne radar, 5-mile sweep. Strong jamming entering side lobes. Echo not visible. Note striations characteristic of semi-synchronous

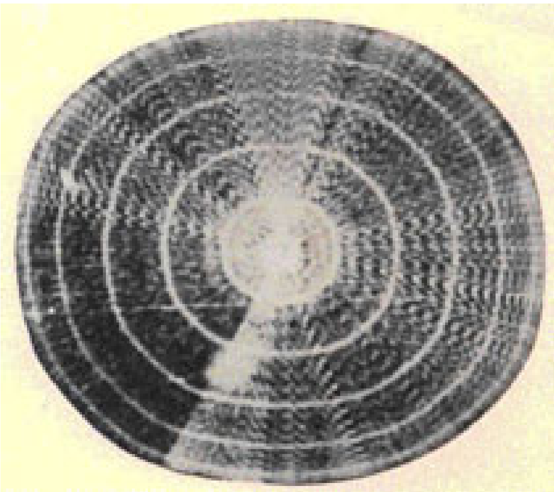


B. Same as A after applying AJ measures. Gain control adjusted and L. O. detuned. Modulating frequency too high for effective use of FTC. Target now visible at 12 o'clock.

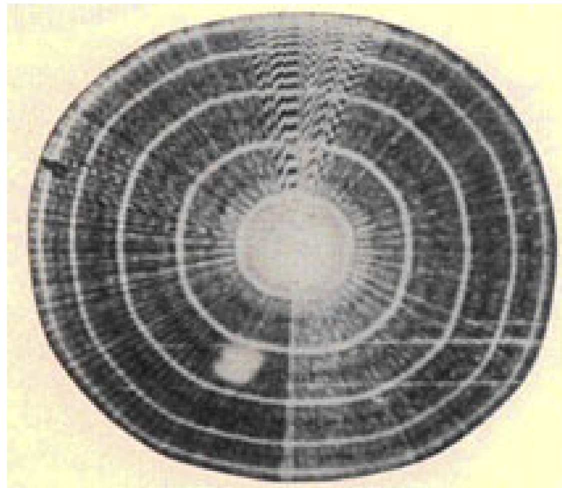
jamming. Dark sector caused by photography.

AJ-Adjust gain to optimum setting. Try detuning L.O.

Figure 3-79. High-Frequency AM Jamming.



A. High-frequency sine-wave jamming entering multiple side lobes.

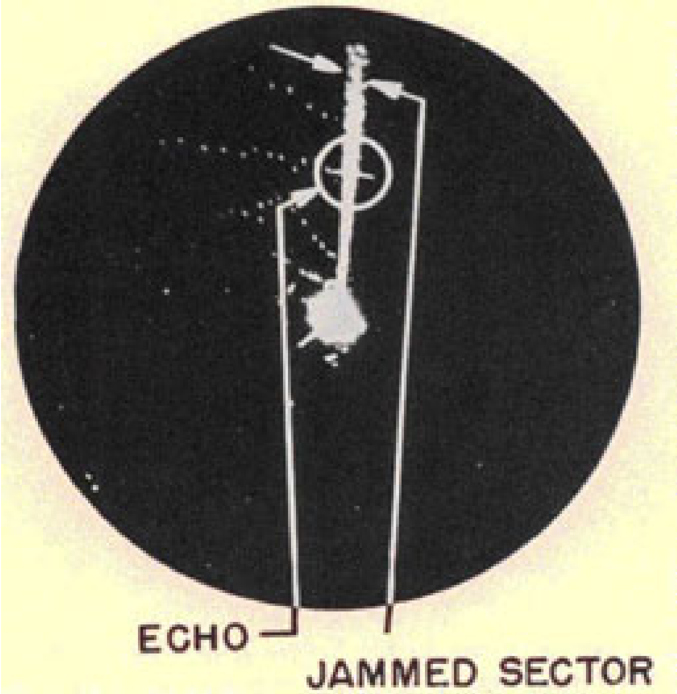


B. Same as A. but jammed sector can now be accurately bisected after reducing gain to eliminate side lobe indications.

AJ-Adjust gain to optimum setting. Try detuning L.O.

Figure 3-80. Taking a Bearing on Jamming.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES



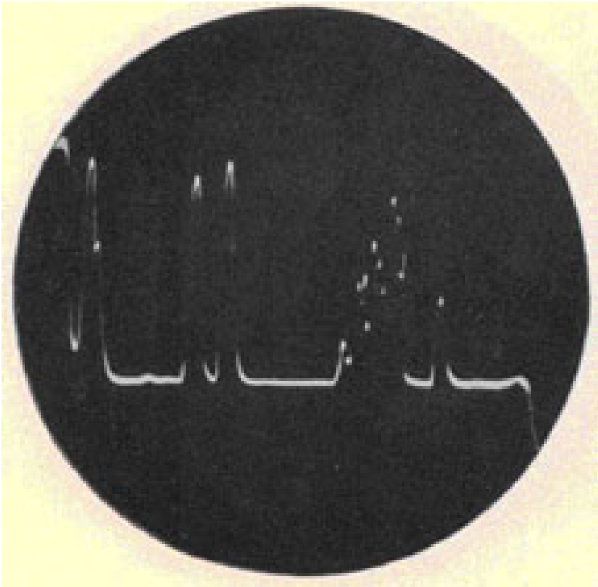
A. Moderate jamming with gain control setting reduced. Jammed sectors produced by random noise, unmodulated CW, and non-synchronous high-frequency modulated jamming are somewhat similar in appearance. Random-noise jamming produces ragged edged sectors. The inner part of the jammed sector looks like excessive snow at reduced gain control settings.

B. Same as A after jamming strength has been increased. Jamming is entering side lobes of radar antenna and echo is obscured. The spiral lines are pulse interference from another radar.

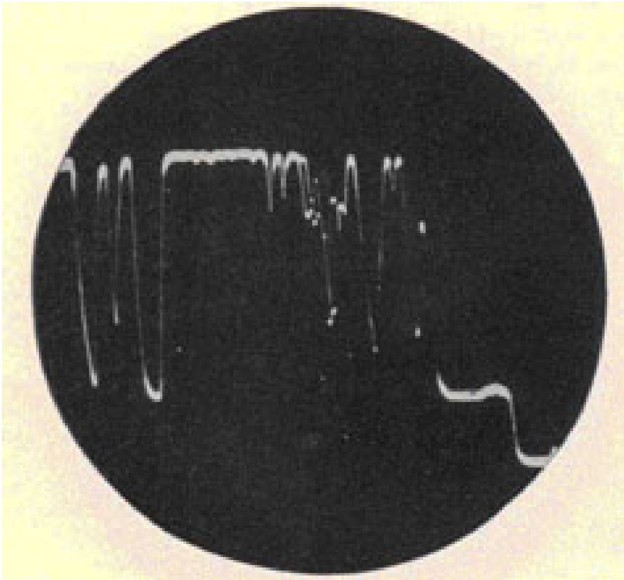
AJ-Adjust gain for optimum setting. Try detuning L.O. Try video filter or FTC.

Figure 3-81. Random-Noise AM Jamming.

RADAR OPERATOR'S HANDBOOK



A. Plane which is fourth target from the left, has just sown Window. Window cause the multiple ragged indications immediately beyond this pip. A target appears at a greater range than the Window.

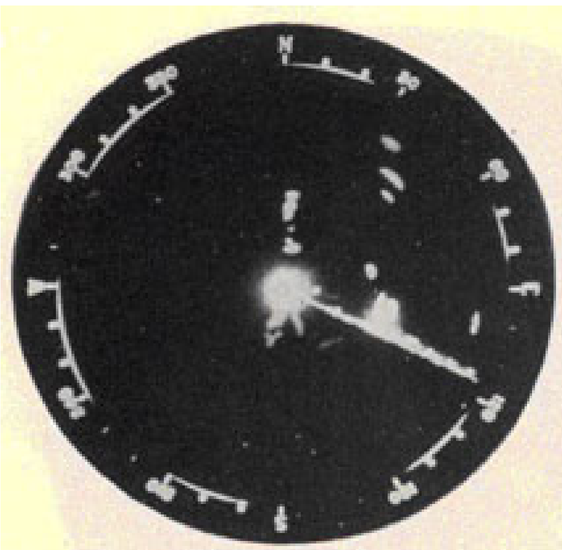


B. Same condition is in A, except at a later time. Plane, which is second pip from the left, is now nearby and has sown enough Window to give saturation returns. No AJ measures have been applied, and the target is lost.

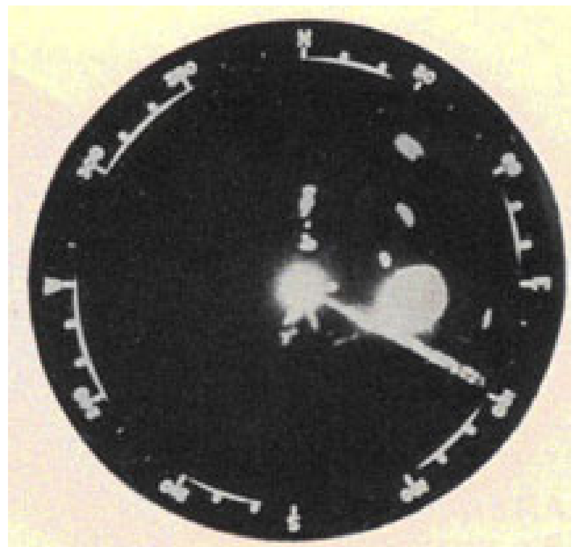
AJ-Turn down gain to prevent saturation. Look at edges of Window area. Cut in FTC. Use shorter pulse length, if available. Use most expanded sweep possible. Look carefully for the relatively fast beating of Window echoes on A scope.

Figure 3-82. Window Jamming.

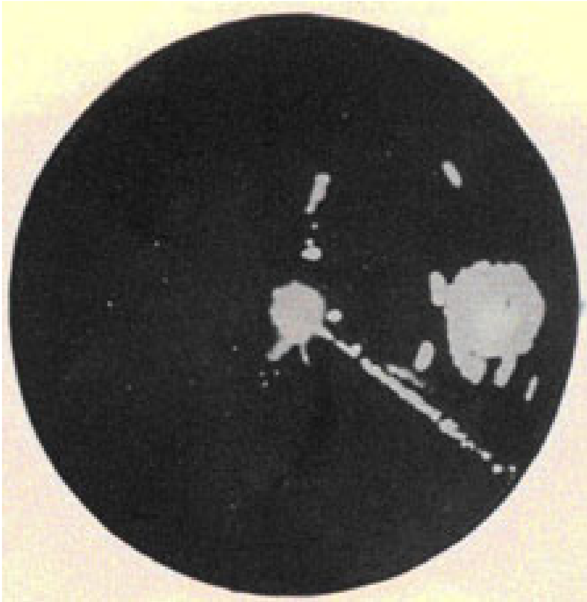
DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES



A. Aircraft at about half range, bearing 100 degrees true is about to sow Window to screen a destroyer, visible just beyond the plane.

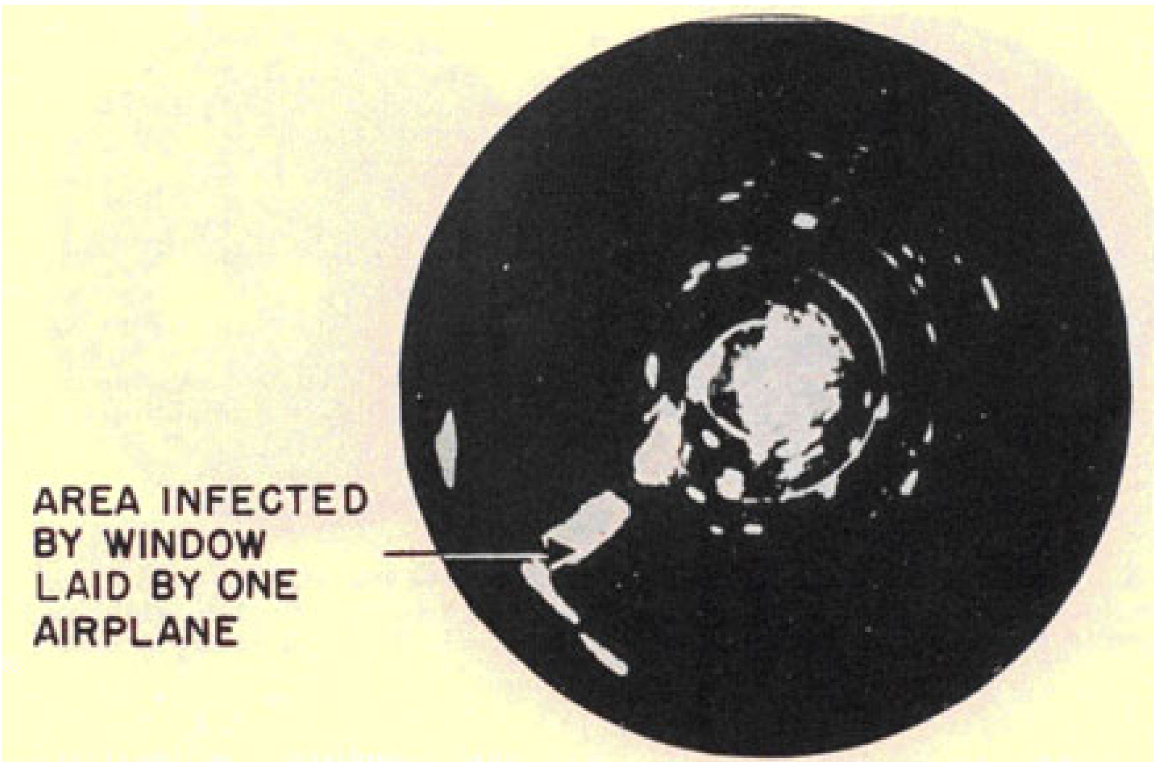


B. Result of Window jamming shortly after photograph in A was taken. Aircraft flew a spiral course while sowing. Destroyer is completely screened.



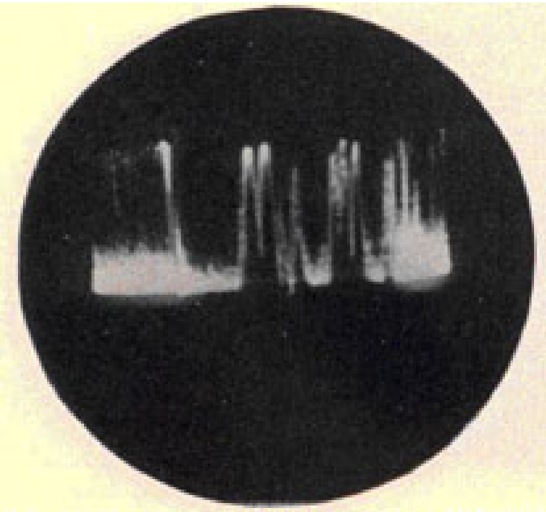
C. Fifteen minutes after photograph in A was taken. Window mass has drifted with wind. Destroyer is again visible on windward side of Window area.

Figure 3-83. Window Jamming on SG Radar.

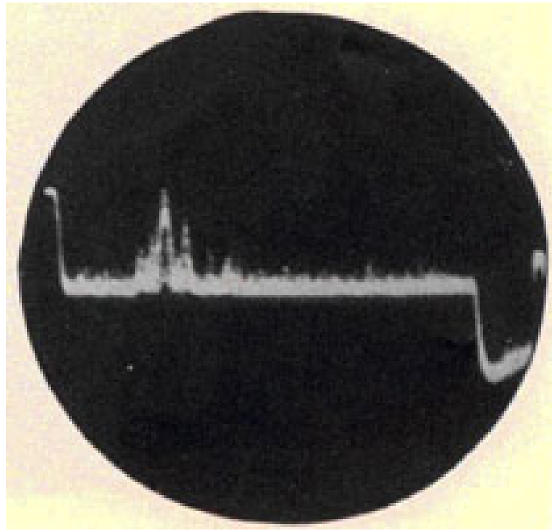


Another example of Window dropped by aircraft. The aircraft probably flew a zig-zag course over the target to be screened.

Figure 3-84. Window Jamming.



A. Window echoes on Mark 4 range scope. Material cut for Mark 4 radar frequency.



B. Echoes from same Window as in A. Little effect because not cut for SG frequency,

Figure 3-85. Window Echoes on Different Radars.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

TECHNICAL ASPECTS OF ANTI-JAMMING TECHNIQUES

The nontechnical radar operator must apply AJ techniques by trial and error. However, much greater proficiency can be attained through a partial technical knowledge of the problems involved. The radio technician must also have some knowledge of AJ methods because the application of some techniques require his presence at the main frame of the radar transmitter.

Generally speaking, the successful application of AJ techniques may be accomplished through an understanding of:

to which it is desired to maintain the pulse shape. Absence of higher frequency side-band components causes the pulse shape to become rounded off or distorted, whereas excessive band width reduces the signal-to-noise ratio because more of the receiver noise components are passed.

CW jamming would theoretically consist of an emission on a single frequency. However, due to instability in the jammer, a small amount of frequency modulation is usually present unintentionally, causing the signal to cover a narrow band of frequencies.

Modulated jamming may either be of the amplitude-modulated or frequency-modulated type. Both types produce similar patterns on the radar scope-AM

1. The nature of echo and jamming (electronic) signals.

2. Radar receiver operation in the presence of jamming.

3. The principles of AJ techniques and devices.

The Nature of Echo and Jamming Signals.

The echo signal. Pulsing, as employed in radar transmitters, is a form of modulation. The transmitted pulse and the corresponding echo pulse may be considered to be a complex modulated signal made up of a carrier and many side bands. If the pulse is square in shape, the frequency spectrum and the relative amplitude of the various components could be illustrated by Figure 3-86.

The spectrum is made up of individual components, which are separated in frequency by an amount numerically equal to the PRR. The width of the spectrum (in megacycles) from the carrier frequency out to the first zero amplitude point is equal to 1/lambda, where lambda is the pulse duration in microseconds. To receive this spectrum, the IF band width of radar receivers may vary from 0.8 to 2.0 times 1/lambda depending on the design of the IF circuits and the extent

being more commonly used. The frequency spectrum for an AM signal will consist of a strong carrier and side bands spaced symmetrically above and below the carrier frequency. If a carrier is modulated by a single frequency, the spectrum will consist of the carrier and only one pair of side hands. Modulating frequencies are referred to as low, medium, and high, and have the following approximate limits:

Low-up to 10 kilocycles
Medium-up to 100 kilocycles
High-100 to 1000 kilocycles.

If the jamming modulation pattern can be made to stand still on the scope (i.e. synchronized) by varying the PRR control on the radar, an estimate of the modulating frequency can be made by counting the number of modulation cycles which occur during a given sweep. For instance, if 4 cycles of the modulation appear on the 40 mile range sweep, the modulation frequency may be calculated to be about 8 kilocycles.

Mixed modulation , consisting of both low and high frequencies used simultaneously, has been employed by the Germans.

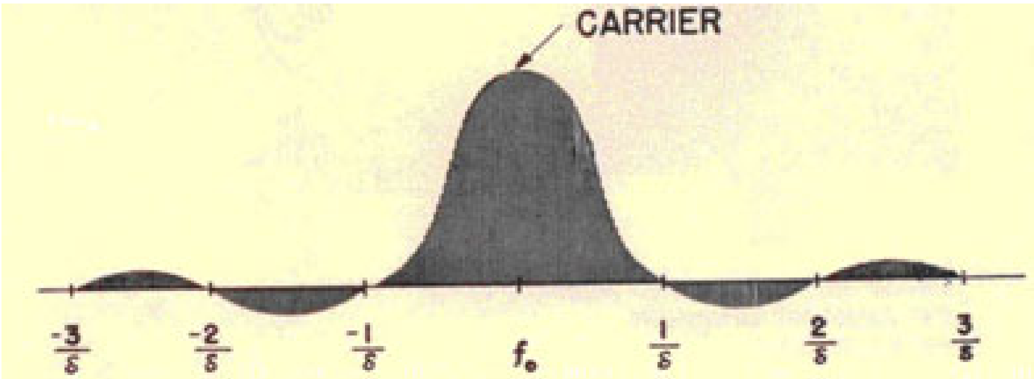


Figure 3-86. The Radio-Frequency spectrum of on echo pulse.

RADAR OPERATOR'S HANDBOOK

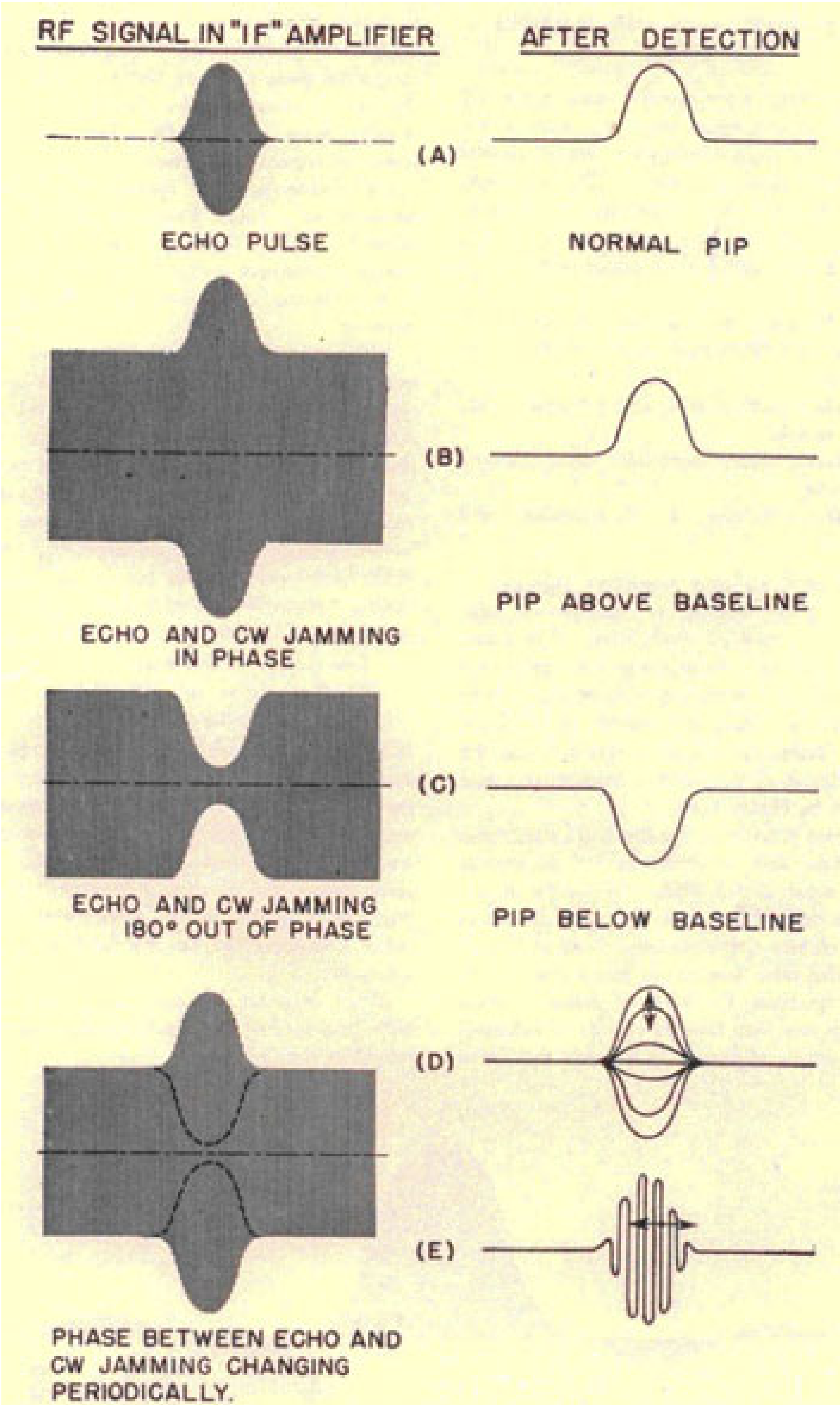


Figure 3-87. Echo and CW jamming changing phase.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

Pulse jamming is a form of AM having a frequency spectrum similar to a radar echo signal. It consists of pulses like those produced by a radar transmitter. The jamming pulses are of the same order of width as some radar pulses except that they usually have a higher PRR and the time between pulses approaches the duration of the pulse. Pulse jamming may also be obtained by 100% modulation of a CW carrier with a square wave.

Random noise modulation. This will consist of a large number of components randomly varying in frequency, phase and amplitude. The total spread of the relatively strong components of the spectrum will usually not exceed 6 to 8 megacycles. In some cases the carrier is suppressed and only one side band is transmitted.

Radar Receiver Operation in the Presence of Jamming.

The IF Channel. When both echo and jamming signals are present in the receiver simultaneously, the echo signal adds with or subtracts from the jamming, depending on the phase relation between the jamming and echo carriers.

If the jammer is on the frequency of the radar, the phasing of the two signals will change from echo pulse to echo pulse within the limits illustrated in figure 3-87 B and C. These figures show that the pip may appear either above or below the normal baseline on the scope. After a number of sweeps the persistence of vision and the persistence of the cathode-ray tube screen will cause a series of pips such as illustrated in figure 3-87 D to appear. If the jammer is not exactly on the radar frequency, the phase relation will also change during the echo pulse at a rate determined by the frequency difference. This condition is shown in E. The pip patterns will not be as distinct as those shown, but will have a blurred, "filled-in" appearance caused by the constant movement of the trace in the directions indicated by the arrows. This condition is illustrated in the photographs shown in figures 3-59 and 3-60. The jammer will usually be "off frequency" because of frequency drift inherent in both the radar and jamming transmitters, and because of the difficulties encountered in constantly monitoring the jamming transmission.

When the jammer is amplitude modulated, the pattern corresponding to the modulation frequency appears during the entire time of the scope sweep, in addition to the effects noted above.

If saturation is not occurring, the pip is superimposed upon the modulation pattern (figure 3-88A). A special case occurs when the per cent modulation of the jammer is 100 percent or over. When the echo occurs at the same time as a trough in the modulation, the pip will be normal (i.e. not double-sided), provided the recovery time of the receiver is short enough, because the amplitude of the jamming is small. Unless the modulation is synchronous, the same portion of the modulation cycle will not occur at the same time on successive sweeps. The modulation will therefore appear to move across the scope and the pip will jump up and down, being sometimes normal and sometimes double-sided (figure 3-88B).

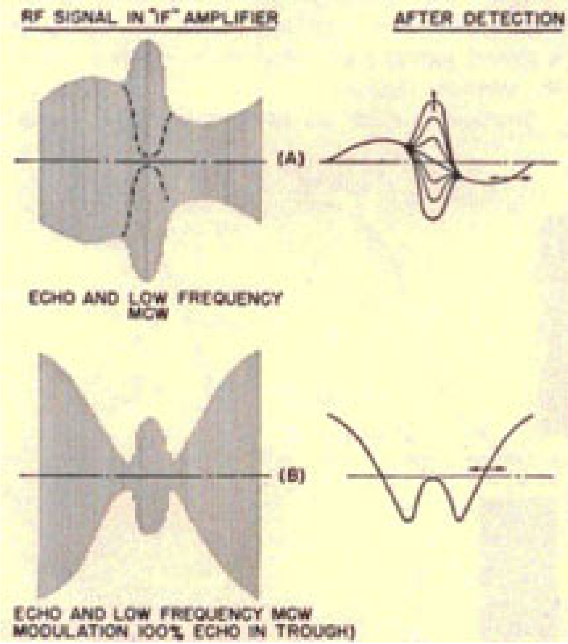


Figure 3-88. Echo in presence of Amplitude-modulated jamming

Overload and Instability in the Radar Receiver

How overload occurs. Many stages of amplification must be used to obtain the high gain required to amplify a small echo signal to a usable level. If a strong jamming signal which is many times the amplitude of the usual echo is amplified by a number of RF and IF stages, the jamming may reach a level sufficient to overload the receiver. This overloading may take the form of plate current saturation or grid limiting, depending upon the components and operating bias of the stage concerned. A receiver stage thus affected will not be able to amplify small changes in amplitude, such as the echo modulation of the jamming. The echo signal is said to be "wiped off."

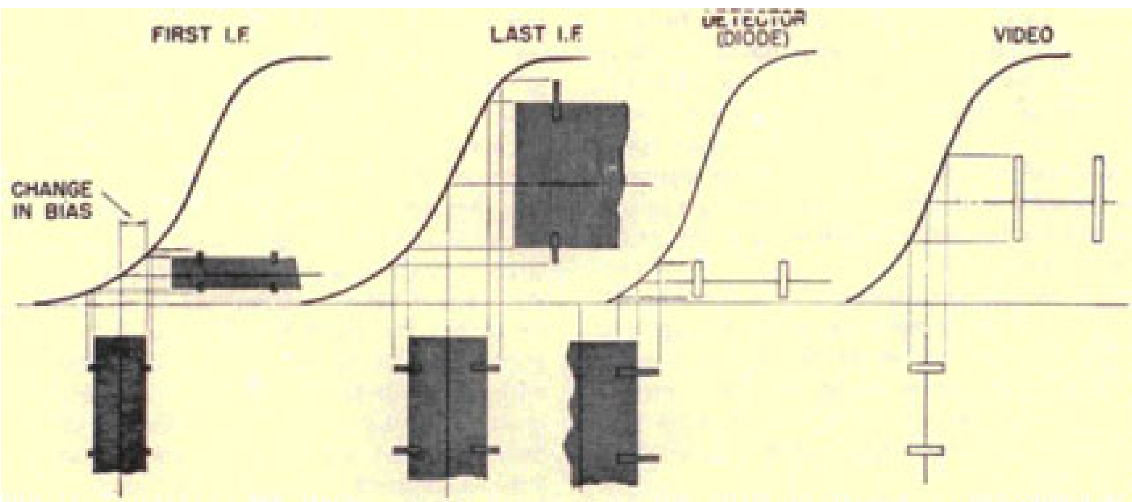


Figure 3-89. Plate-Current saturation on Positive Peaks Occurring in Last IF Stage.

Prevention of overload. For purposes of illustration, let us assume that overload is occurring due to plate-current saturation on the positive peaks in the last or next to the last IF stage (figure 3-89). It will be noted in figure 3-90 that the echo may be restored in the output of the last IF amplifier by reducing the setting of the IF gain control, but that it is double sided.

In this case gain control is accompanied by changing the amplification of the first IF stages-one of the methods frequently used. No change is made in the operating point of the last IF stages by manipulating this control. The echo signal is reduced in amplitude by the same ratio as the jamming but the echo is now amplified by the last IF stage instead of being wiped off". Weak echoes may not be visible after the IF gain control has been reduced because of the loss in amplifier gain.

Another method of seeing a pip in the presence of jamming, under certain conditions, is to turn the IF gain up instead of down and to observe the pip as a black opening at the base of the jamming pattern. This can be done only with jamming having a relatively high percentage of modulation, and is dependent upon the recovery time of the receiver. Overload will occur in certain portions of the jamming modulation cycle but not necessarily in the troughs. The amplitude of the jamming in the troughs may be so small that the echo may appear as a normal pip at the baseline which makes a gap in the jamming pattern.

Overload is made less likely in radar receivers of

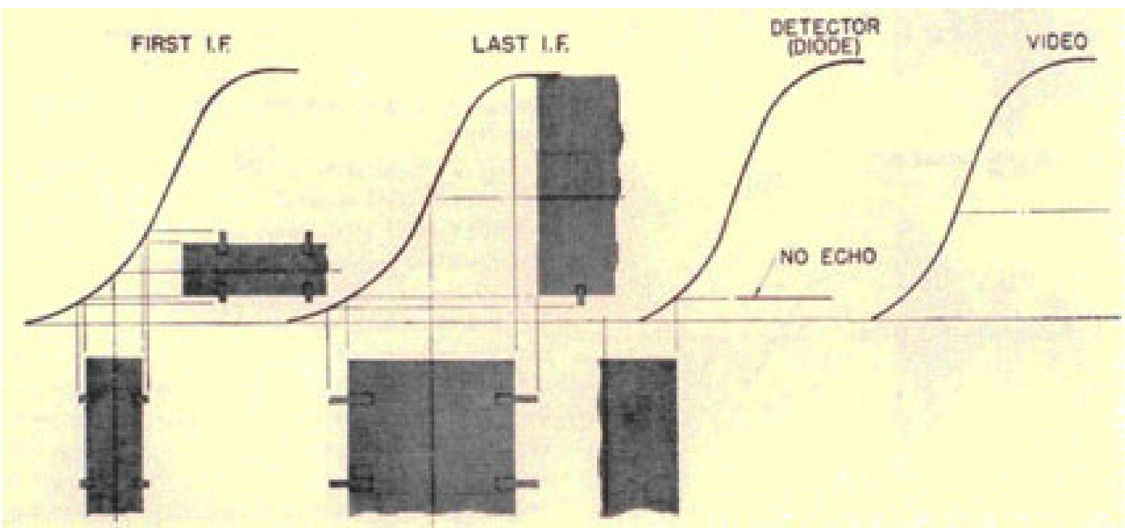


Figure 3-90. Receiver Gain Reduced-No Overload Occurring.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

present design by the use of back bias" circuits. By means of these circuits the signal level is made to control automatically the operating point of various stages in the IF amplifier. The presence of the strong jamming then causes the grid bias of an IF stage to change from its usual value to a much higher negative value. As a result, the input signal may still be relatively large without wiping the pip off on one half of the input cycle. In effect, the tube circuit is now acting as a Class "C" amplifier, and is actually discriminating against the jamming in that the average amplification of the stage for the jamming signal has been reduced relative to that for the echo.

In order to make full use of this principle, the operating point of each IF stage must be suitably adjusted. "Unamplified back-bias" is used in the earlier stages; in the later stages, where a greater voltage swing is required, "amplified back-bias" (AVC or IAVC) is used. IAVC (Instantaneous Automatic Volume Control) is similar to AVC except that very short time constant circuits are used. AVC circuits tend to remove jamming modulations because of their degenerative characteristics. Time constants determine just how high a modulation frequency is removed. The recovery time constant also determines the effect on pulse jamming, Window, and other clutter.

Receivers are in production with the following back bias schemes:

(a) Unamplified back-bias for all IF stages-time constants shorter or equal to radar pulse duration.

(b) Unamplified back-bias for first IF stages, back-bias (AVC) for last IF stages.

(c) Short time constant amplified back-bias (IAVC) for last stages.

The modulating frequency appears in greater amplitude at the output of the detector as the modulation percentage increases. Under these conditions, it will sometimes be noted that a jammed echo may be visible on the A scope but only a blanked out sector with no echoes visible appears on the PPI. This blanking may be caused by grid limiting in the video amplifier. However, when only a cathode follower

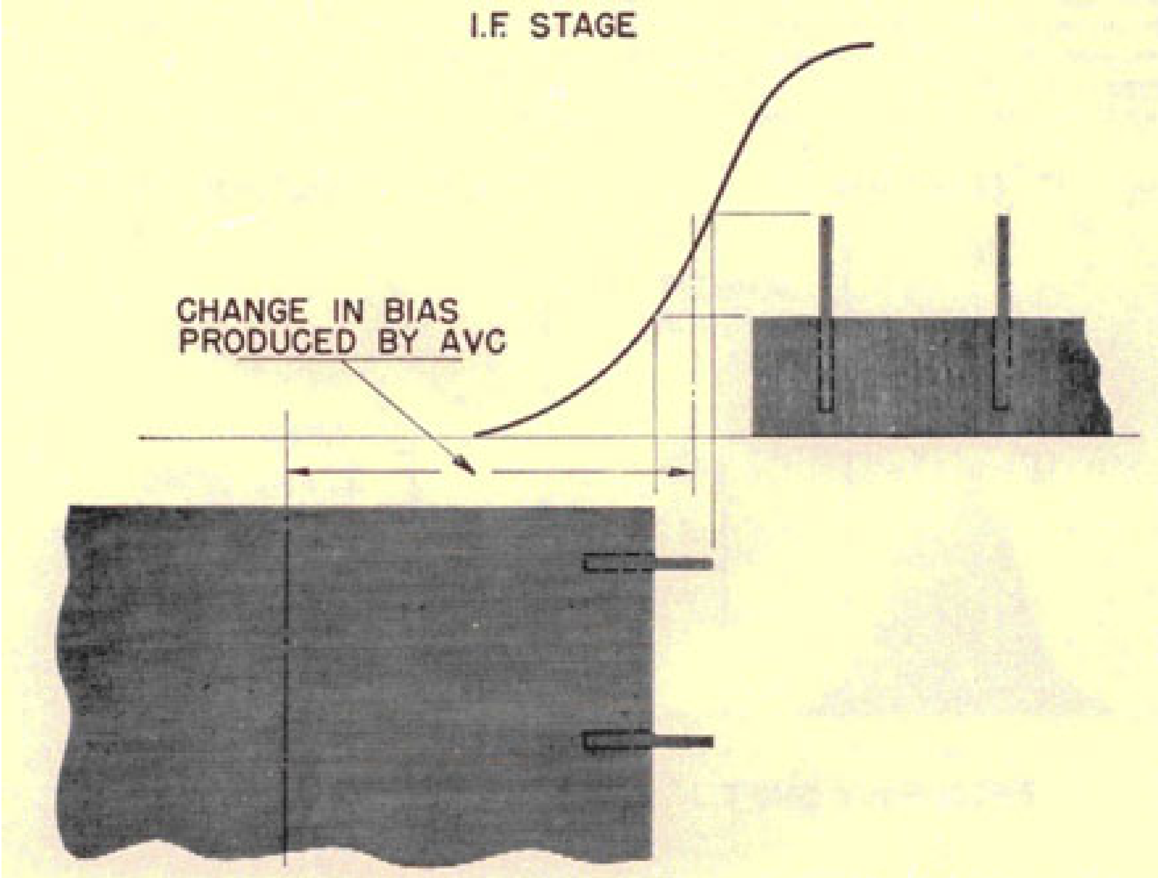


Figure 3-91. Use of AVC (Back Bias) in IF stage.

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is used after the detector, the difficulty may usually be traced to the limiter used to prevent the PPI screen from overloading. Some of our present radars are now provided with a video gain control. Suitable adjustment of this control will at least make the jamming visible as a bright sector on the PPI. However, since the PPI is an "intensity modulated" device, small changes in intensity, such as an echo might produce in the presence of strong jamming, are not as easily detectable as on the A scope.

In the presence of jamming, another effect comes into play-the large jamming signal may cause the receiver to become unstable. This may be the result of "ringing" or oscillation in some of the IF tuned circuits. Such a condition may sometimes must constantly monitor the radar transmissions by means of an intercept receiver capable of looking through" the jamming he sends out. However, even with constant monitoring it is almost impossible to keep the jammer exactly on frequency. Some of the following techniques may be useful in combating this jamming, after the radar gain control is adjusted to prevent overloading the receiver.

Take advantage of frequency difference. Usually the jammer will be slightly off the radar frequency. This allows the beat between the carrier of the echo and the carrier of the jammer, and other strong components around the two carriers, to be used as an echo indication. The strong complex beat may produce an easily identified discontinuity in the jamming pattern to he observed on the scope.

be remedied by a careful setting of the gain control or by changing the response time of the AVC circuit.

The principles of AJ techniques

The enemy will attempt to tune his jammer so that the center of the jammer frequency spectrum corresponds to the center frequency of our radar echo spectrum. This is a difficult thing to do, and keeping the jammer exactly on the radar frequency over a long period of time is even more difficult because the frequency of both the jammer and the radar transmitters vary independently. Therefore the enemy

Figure 3-92 shows a medium-frequency amplitude. modulated jammer having side hands marked (1) and (3). In (A), the response of the IF amplifier, as indicated by the curve showing the "acceptance hand" is very nearly but not actually zero at the frequency of component (3). Therefore, if component (3) is strong enough, it will pass through the IF amplifier and beats will he produced after detection with components of the echo.

Figure 3-92(B) shows the spectrum present at the input of the video amplifier. The portion under

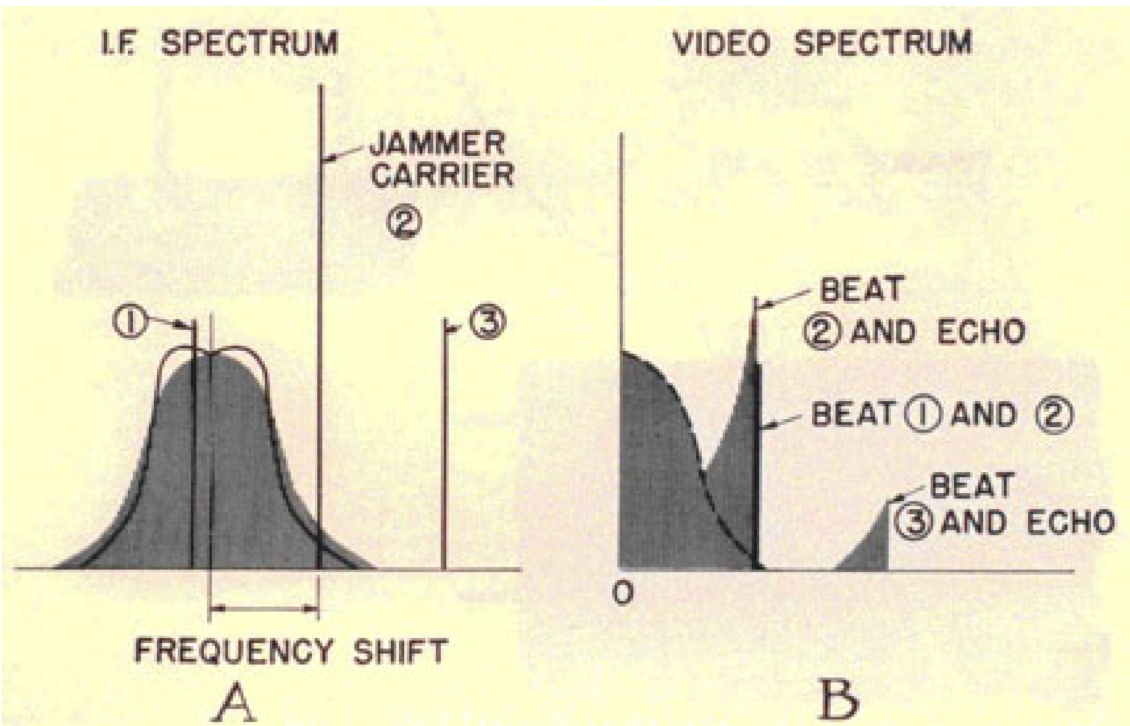

Figure 3-92. Utilizing Beat between Echo and Jamming as Echo Indication.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

the dotted line shows the spectrum that would be present if no jamming were occurring. The beating that would result is more complicated than indicated, and the amplitudes of the frequencies shown are probably not entirely correct. The beat between (1) and (2), which produces the confusing pattern on the scope, occurs continuously while all other beats occur only during the time that the echo is present. Previously the video amplifiers in our radar equipments have not had sufficient frequency range to pass the beat between (3) and the echo. The present tendency is to improve the frequency response of video amplifiers so that the frequency range is about equal to the width of the IF acceptance band. This suggests the use of the beat between (3) and echo as an echo indication and removing all other frequencies below this band of frequencies by means of suitable video filters.

The AJ technique used in this particular case is to shift the radar frequency a small amount so that the jammer carrier is attenuated by placing it at the outer edge of the IF acceptance band. This tends to reduce the amplitude of the objectionable beat between components (1) and (2).

It is desirable for the operator to have direct control over small frequency variation so that the most readable echo-jamming pattern may be obtained. On equipments having a transmitter power control at the receiver-indicator, slight frequency changes may be made by varying the transmitter plate voltage. Multimoding may occur with transmitters employing magnetrons if the plate voltage is changed too much from its normal value.

Local oscillator tuning. The local oscillator tuning provides another means of getting "out from under the jamming" which is directly under the control of the operator. Changing this control causes the spectrum of both the jamming and echo signals to appear about a different center frequency in the IF amplifier, but the acceptance band of the IF remains the same irrespective of the setting of the local oscillator. However, the IF amplifier output will drop off when the center frequency of the signal no longer corresponds with the center frequency of the IF acceptance band, because some of the components will be more attenuated than in normal operation. For this reason changing the L. O. tuning will also act like a gain control and will tend to prevent receiver overload.

When both jamming and echo signals are present in the IF the effect may be used to discriminate against the jamming when the jamming and echo carriers are not on the same frequency. A slight frequency variation may add materially to the effect obtained. Figure 3-94 illustrates what can be done with L.O. tuning. Here we are attempting to shift the greater part of the jamming spectrum outside of the receiver acceptance band, without losing too many of the echo components. The carrier of the jammer is attenuated considerably, but continuous beating between the side-band components of the jammer will still be visible on the scope. Thus, the result of detuning is not to remove all or the jamming signal, but only to cause the echo signal to become strong enough relative to the jamming to permit a definite discontinuity to be seen. In many cases, though, the jamming may be almost entirely removed. In a

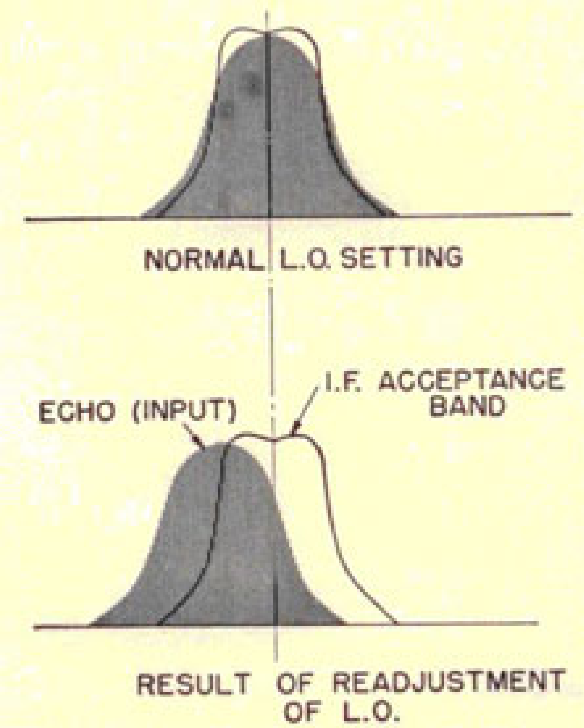

Figure 3-93. Effect of Adjusting Local Oscillator Tuning Control.

complicated case of jamming the best method of observing the echo may be to advance the gain control so as to obtain limiting of the jamming pattern while simultaneously varying the L.O. tuning. The echo would probably appear, if at all, as a dent in the baseline. When the local oscillator is detuned, however, extreme care should be taken to note the correct setting of the control, so that the radar can be restored to normal operation as soon as the jamming stops.

IF filters. The IF rejection slot is so called because it puts a "slot" in the IF acceptance band of the receiver.

The small band of frequencies that it removes from the acceptance band will not affect the shape of the echo appreciably. The characteristics of such a filter suggest its use against CW jamming and amplitude modulated jamming. The principle used is that of removing the carrier of the jamming interference so that beating will not occur between side bands and the carrier of the jamming. Beating will still occur between the two jamming sidebands but at higher frequency and with smaller amplitude.

If another slot is available, it could be adjusted to eliminate one of the jammer sidebands. As the slot is moved across the acceptance band of the receiver (as indicated by the arrows) several minimums in the jamming pattern will be noticed as the sidebands are passed. Some slight improvement may be

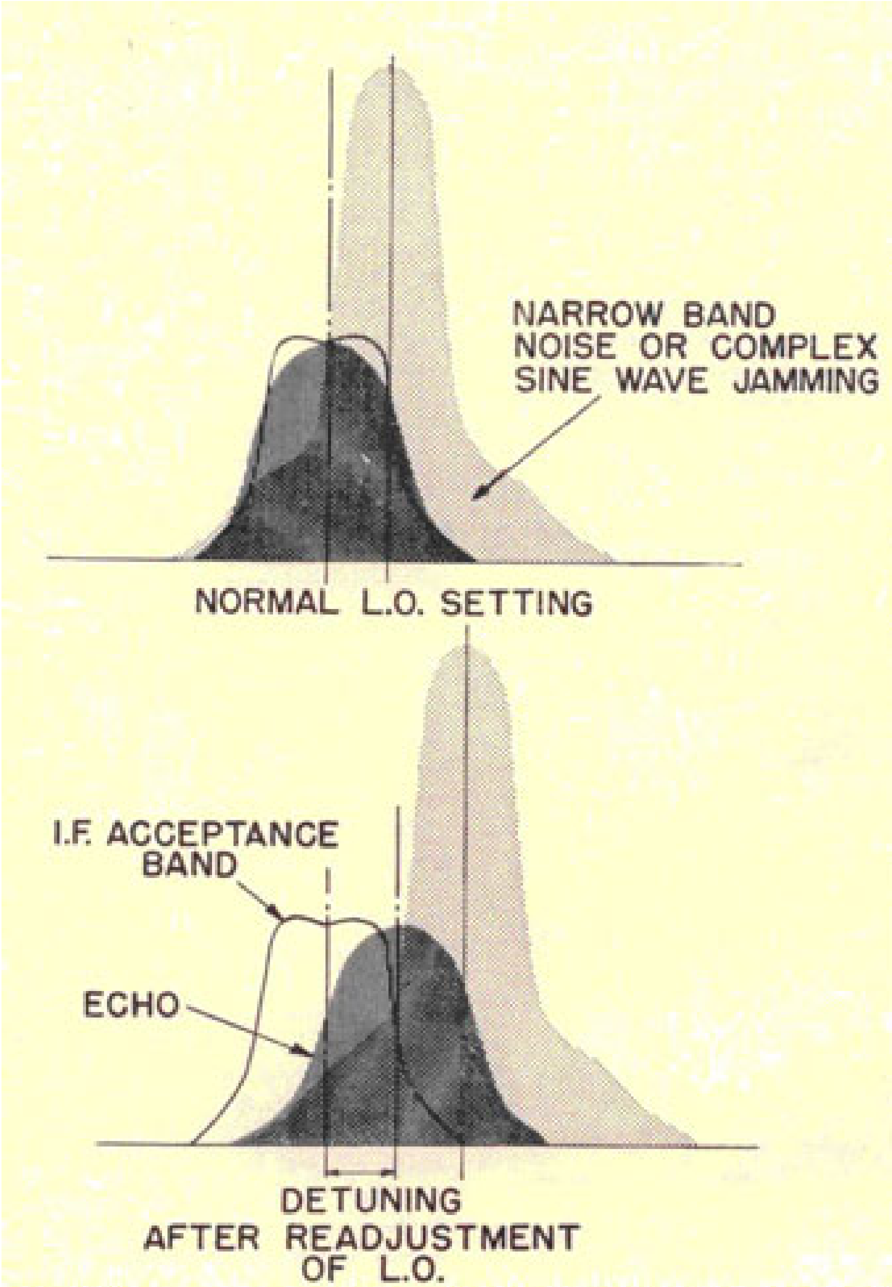

Figure 3-94. Using L.O. tuning to Discriminate Against Jamming.

DEFENSES AGAINST ENEMY RADAR COUNTERMEASURES

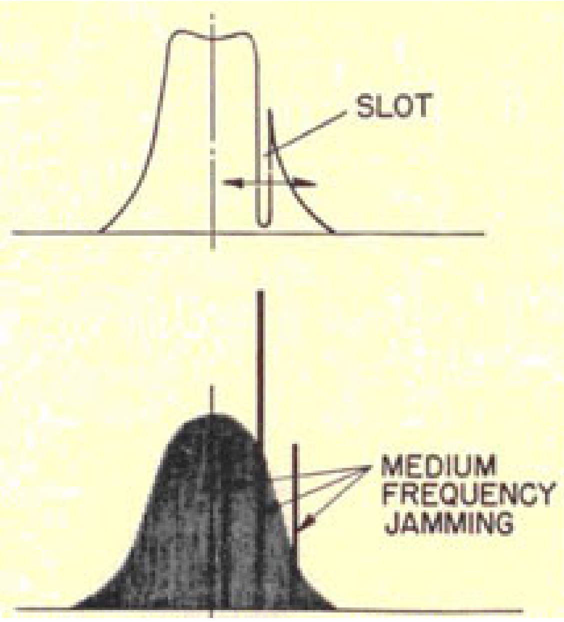

Figure 3-95. Setting IF Rejection Slot to eliminate carrier frequency of jammer.

expected in removing the carrier of amplitude modulated noise jamming, but since there are so many other components present, the improvement may not be very noticeable.

Video filters. The types of filters now used as AJ devices may be classified as fast time constant, high-pass, and band-pass. The purpose of using them is to remove objectionable modulation frequencies or to improve the visibility of the echo. The elimination of strong modulation components also prevents overload in the video amplifier. Filtering may be accomplished by relatively simple R-C circuits or with more complicated L-C circuits employing many sections.

When the modulation frequency spectrum of the jammer consists only of low or medium frequencies (i.e. less than 100 kc), a simple R-C filter is satisfactory for removing the jamming modulation. This is accomplished by introducing fast time constant coupling (FTC), preferably between the detector and the first video stage. The time constant of the coupling condenser and the grid resistor of the video stage is made to equal passage of the jamming frequencies, but when the jamming includes high frequencies, the filter is ineffective. If the jamming modulation consists of a number of components scattered throughout the echo spectrum, removal of the jamming modulation becomes more difficult. Any simple filter which would attenuate or remove these widely scattered modulation frequencies would also attenuate the echo in the same ratio. However, a sharp cut-off high-pass filter may be used to advantage when the jammer and echo carrier frequencies are slightly different. For example, if the jammer frequency differs from the radar frequency by 0.5 megacycle, a 500 kilocycle beat exists for the duration of the radar pulse. If a 500 kilocycle high-pass video filter is used it will pass the 500 kilocycle beat and attenuate all lower frequencies. As a result, the jamming modulation is removed and a "beat frequency echo" appears in place of the usual echo. This echo may be filled-in or have a more fuzzy appearance than the usual echo, but nevertheless it is usable. Extra video gain must be used, for otherwise only strong jamming will produce a beat large enough to be observed.

Short time constant AVC and IAVC circuits have been designed which will remove frequencies up to 10,000 cycles per second. However, it is sometimes impossible to use these quick-acting circuits in the presence of jamming because of the tendency of circuits in the receiver to break into oscillation.

The problem of removing jamming modulation is somewhat complicated when barrage jamming (several jammers having their carrier frequencies staggered over a given band) is encountered, because of the beat frequencies set up between jammers. A *band-pass* filter may be used in this case. This filter will tend to remove the modulation frequencies in the low side of its characteristic and the jammer beat frequencies on the high side.

Video filters must be used cautiously with fire

one to five times the radar pulse length. In general, this type of filter is very effective in removing low frequencies, but it becomes less effective as the modulating frequencies increase due to its poor cut-off characteristics. The effect of such a filter is to allow the echo frequencies to pass without much distortion, while preventing the control radar equipments employing pip-matching. High-pass and band-pass filters remove nearly all of the frequency components of the echo, which necessitates observation of the beat frequency echo both for ranging and pip matching. When the jamming is strong enough, which means that it exceeds a certain jamming-to-signal ratio, depending upon the equipment in question, the amplitude of the beat will be proportional to the amplitude of the echo. If the jamming is weak, the amplitude of the beat varies with the amplitude of the jamming-an undesirable condition. Therefore, serious angle errors will result when high-pass or band-pass filters are used in the

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presence of weak off-target jamming. They should not be used against weak jamming when angle information is desired, unless the jamming source is definitely known to be located on the target.

The insertion of filters in the video amplifier, with the exception of the simple R-C filter, delays signals passing through the amplifier. Such delay results in range errors if not compensated for, and different filters introduce different delays. When a selection of several types of filters is available, time delay compensation is applied to make the total delay (filter delay plus compensation) the same for all filter positions. It is then possible to "spot" the range a given amount no matter which filter is used.

* U. S. GOVERNMENT PRINTING OFFICE: 1945-6388S9.

Previous Part   Radar Home Page   Next Part

Version 1.00, 4 Sep 05

PART 4

SPECIFIC EQUIPMENT

ORDER OF PRESENTATION

PART 4

SG RADAR

RADAR OPERATOR'S MANUAL
SG RADAR

CONTROLS

Range and train indicator.

Working with the SG, the operator is concerned primarily with the range and train indicator unit from which he can control the entire radar gear. A close-up of this unit is shown in figure 4-SG-1.

All the controls on the range and train indicator may be divided into three groups: power, operating, and pre-set. All the power controls are grouped on the left and extend from top to bottom of the unit, except for the dial lights switch, which is at the far right of the pre-set group. The second group, operating controls, extend along the center of the panel. The third group is the bottom row of pre-set controls.

Identification and function.

It is important to be able to identify, and to know the functions of all of the controls. For ease in locating and identifying, all controls in figure 4 SG-1 are either numbered or lettered.

1. The switch marked A is the remote control for the main-power switch at the transmitter-receiver unit.

2. Meter B is identical to one located on the transmitter-receiver unit, and indicates *line voltage*. This meter should read between 110 and 120 volts AC. If it does not, call the maintenance man.

3. The other meter, C, indicates *transmitter current* when switch K is in NORMAL position. Transmitter current as indicated on meter C is controlled by the setting of the variac (E). The variac should be set so that the transmitter current reading on meter C is between 15 and 25 milliamperes. If this reading cannot be attained, notify the maintenance man. With Switch K in MONITOR or RECEIVER TUNE position, meter C duplicates respectively RF. monitor and tuning indicator meter readings at the transmitter and receiver

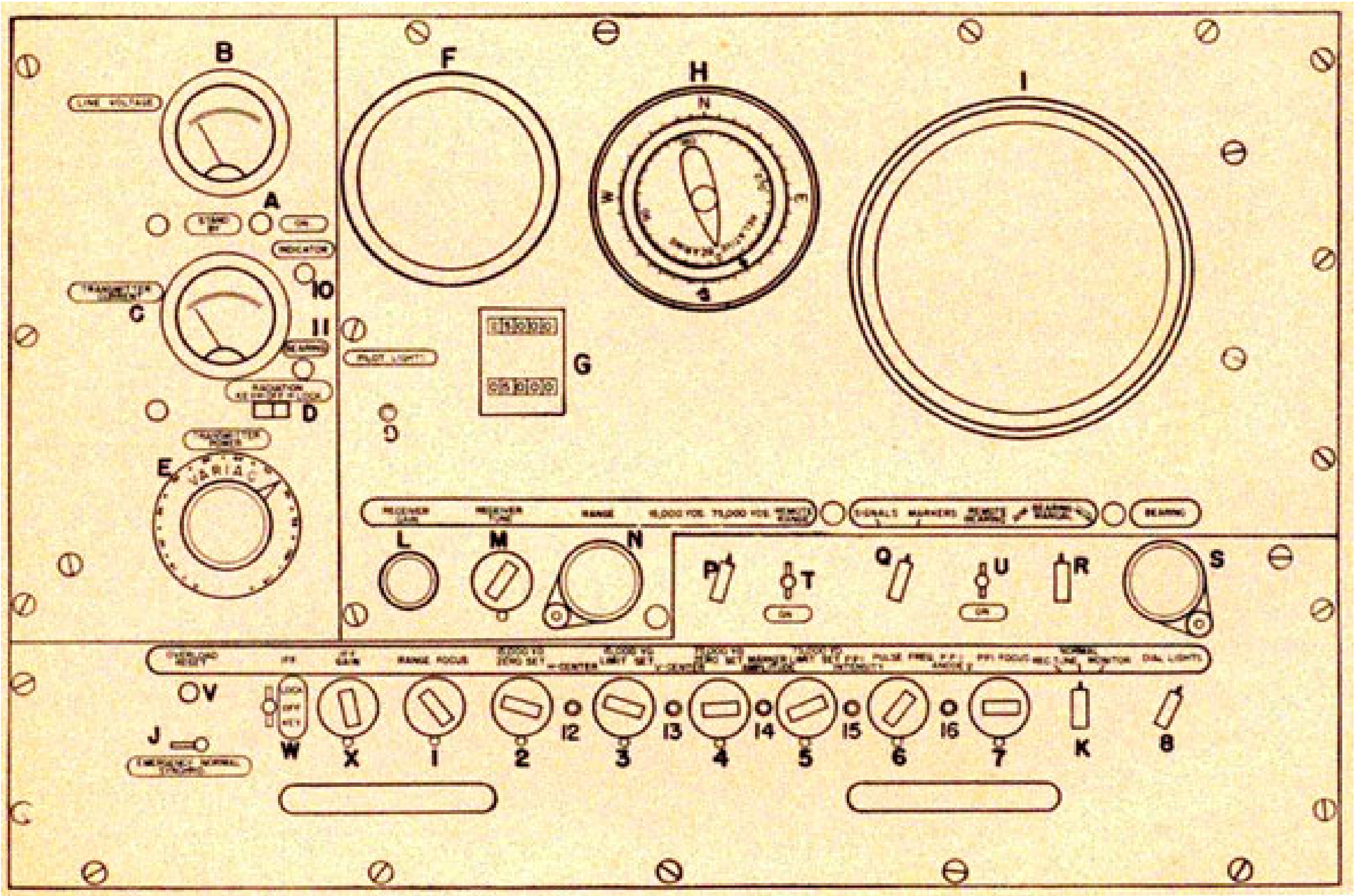

Figure 4 SG-1. Range and train indicator unit.

4-SG-2

SG RADAR

unit. When switch K is an the RECEIVER TUNE position, it should read from 30 to 40 depending upon how well the receiver is tuned. The receiver should be tuned for maximum meter deflection. The meter reading in the MONITOR position will vary from time to time according to the way it is adjusted by the maintenance man. The operator should check the value at the start of his watch, and periodically thereafter, in order to determine whether any changes occur. The maintenance man should be notified immediately of any change.

4. The *radiation switch* D controls intermittent and continuous operation of the transmitter. For intermittent operation, switch D must be held in

base on the range scope. Thus, lining up the step with the blip on the range scope, the range of the target can be read directly from the range counters.

13. There are two range scales. 15,000 yards and 75,000 yards. Switch P permits the operator to select either of the two ranges.

14. Switch Q allows the operator to receive either signals or range markers on the range scope and PPI. Normally this switch is on SIGNALS. In order to insure that the gear will give accurate ranges, the operator must cheek frequently (at least once each watch) the range calibration by switching range markers to the scope. This procedure is described

KEY position, as there is a spring action that automatically returns the switch to OFF position. LOCK position is for continuous operation.

5. *Variac* (E) controls the power supplied to the transmitter.

6. The scope (F) is the *range scope*. Ranges are read directly on the *range counters* (G). A modified method for quick and approximate readings is to place a calibrated scotch tape scale on the "A" scope below the sweep. The same can be done at the PPI (I) by drawing with india ink 5,000-yard circles for the 15,000-yard range; then, on the 75,000-yard range, these circles will be 25.000 yards apart.

7-8. Bearing is read on indicator H and PPI (I). True bearing is read from the outer scale, while relative bearing is read from the inner dial, when *synchro switch* (J) is in NORMAL position. If ship's gyrocompass repeater system should fail, switch J must be thrown to EMERGENCY for equipment to operate, giving relative beatings only on the outer dial.

9. When the radar is operating, switch K is in the NORMAL position. The other positions, RECEIVER TUNE and MONITOR, are for purposes stated in 3 above.

10. Receiver sensitivity is controlled remotely by the operator through *receiver gain control* (L).

11. Receiver's tuning is controlled remotely by the operator with *receiver tune control* (M) This is set for maximum return signals.

12. The *range crank* (N) is geared to the range counters and also moves the step in the time later, in the section on Calibration.

15. The antenna's rotation may be controlled either manually or automatically by switch R. From its center position moving switch R to right gives automatic clockwise rotation; moving it to left gives automatic counterclockwise rotation. There are four positions for four speeds on either side of center.

16. *Remote range switch* (T) and *remote bearing switch* (U) permit transmission of ranges and bearings, respectively, to range and bearing indicators located on the bridge, gun control, torpedo control, and plotting rooms. At these stations there are selector switches for cutting in either range and/or bearing indicators. As a rule, remote range and bearing are always in the ON position at the range and train indicator and OFF at the selector switches when bearings or ranges are not desired.

17. As a safety precaution against overloading the transmitter, there is a relay which trips during any overload condition. This relay can be reset by the operator by pushing *reset button* (V).

18. Switch W will determine the positions OFF, INTERMITTENT, and CONTINUOUS operation for IFF equipment when it is installed,

19. Switch X adjusts the IFF gain.

20. *Range focus* (1), permits the operator to adjust the sweep on the range scope, permitting a sharp, even trace for the entire width of the scope. This setting is made on installing a new tube.

21. 15,000-yard *zero set* (2) adjusts the calibration for the lower end of this range scale.

RADAR OPERATOR'S MANUAL

22. 15,000-yard *limit set* (3) adjusts the calibration for the upper end of this range scale.

23. 75,000-yard *zero set* (4) adjusts the calibration for the lower end of this range scale.

24. 75,000-yard *limit set* (5) adjusts the calibration for the upper end of this range scale.

25. Pulse frequency (6) controls the pulse repetition frequency. There are three adjustments, A, B, and C, which are used to reduce interference from other radars of approximately the same frequency. The control (6) is set on the letter giving the minimum interference. This control also is used for identifying second-sweep echoes. More will he said about this in the technique section.

26. *PPI focus* (7) permits the operator to adjust the sweep on the PPI for a sharp, even trace.

27. *Dial lights switch* (8) controls the intensity of lights on the PPI, bearing dial, and counters. *Pilot lights switch* (9) controls light intensity for the red and amber lights opposite the stand-by and radiation switches (this control has been omitted on later models).

28. There are five screwdriver adjustments with which the operator should not tamper once the set is operating normally.

that he can make any adjustment automatically, even in complete darkness.

TURNING ON AND OFF

Turning on.

Let us assume that the transmitter and receiver unit are ready for operation. When starting the gear for the first time, check to see that the controls are set as follows:

1. Turn the main-line power at the remote control switch (A) to STANDBY.

2. Set the radiation switch (D) in the OFF position.

3. Turn the variac (E) to zero (extreme counterclockwise).

4. Place synchro switch (J) on NORMAL position.

5. Turn receiver gain (L) down.

6. Throw signal-markers switch (Q) to SIGNALS.

7. Turn bearing switch (R) to NORMAL.

8. Set rec-tune, normal, monitor switch (K) to NORMAL.

Steps 1 through 8 represent the normal settings of the range and train indicator unit when equipment is on STANDBY, and from which the SG can be placed in operation as follows:

H center adjustment (12) centers the time base on the range scope from right to left.

V center adjustment (13) centers the up and down position of the time base on the scope.

PPI anode 2 (16) adjusts the sweep and signal intensity of the PPI screen.

PPI intensity (15) adjusts the intensity of the signal.

Marker amplitude (14) adjusts the height of the range markers, which should be from 3/4 inch to 1 inch in height.

29. There are two fuses with which the operator should he familiar. These fuses are located on the front panel near the *transmitter current meter* (C). One is marked INDICATOR F-902 (10), and the other is marked BEARING CONTROL F-901 (11). If, for any reason, the antenna or indicator should stop functioning, the operator should check these fuses before sending for the maintenance man There is a further description of these fuses in the section on Operational Technique. So far the controls on the range and train indicator unit have been identified. The operator should become so familiar with these controls

1. Turn the standby-on switch (A) to the ON position. The amber pilot light will indicate that power is available. Check the line voltage on meter (B), which should read between 110 and 120 volts.

2. Throw the radiation switch (D) to LOCK position. After about one minute, the red pilot light will glow, indicating that the transmitter is ready.

3. Turn the variac (F) slowly to the right until the transmitter current meter reads 25 milliamperes or less.

4. Turn the receiver gain control (L) up until about 3/8-inch grass appears on the range scope.

5. Start antenna rotation by turning the switch (R) to right or left.

Turning off.

In order to shut down the equipment the above procedure should be reversed.

1. Stop antenna rotation by turning switch (R) to the center position, leaving antenna on 000 degrees relative bearing.

SG RADAR

2. Turn receiver gain control (L) down.

3. Return variac (F) to zero (extreme counterclockwise).

4. Turn radiation switch OFF.

5. Throw the power switch (A) to STANDBY.

CALIBRATION

Calibration of the range counters.

To make sure that the equipment will give accurate range readings, the operator should check the calibration of the range counters at least once every watch (every four hours). To do this, the range selector switch (P) is first set to the 15.000-yard position and the signal-markers switch (Q) to the MARKERS position. Markers representing divisions of 5,000 yards appear along the time base on the range scope. The operator now turns the range crank (N) until the 15,000-yard marker just begins to "pull down" into the step. The diagram in figure 4 SG-2 illustrates how the step should appear when adjusted to the correct position. If accurate, the range counters should read exactly 15,000 yards. Next, the step is lined up with the center of the 5,000-yard marker. Now, the counter should read exactly 5,000 yards.

The operator also checks the counters on the 75,000-yard range scale, Then, if the selector switch is in the 75,000-yard position, a series of markers will appear on the time base, each representing distances of 5,000 yards. The appearance of these markers will vary somewhat on different installations, and this difference must be clearly understood if the calibration is to he done correctly. *The zero marker may or may not*

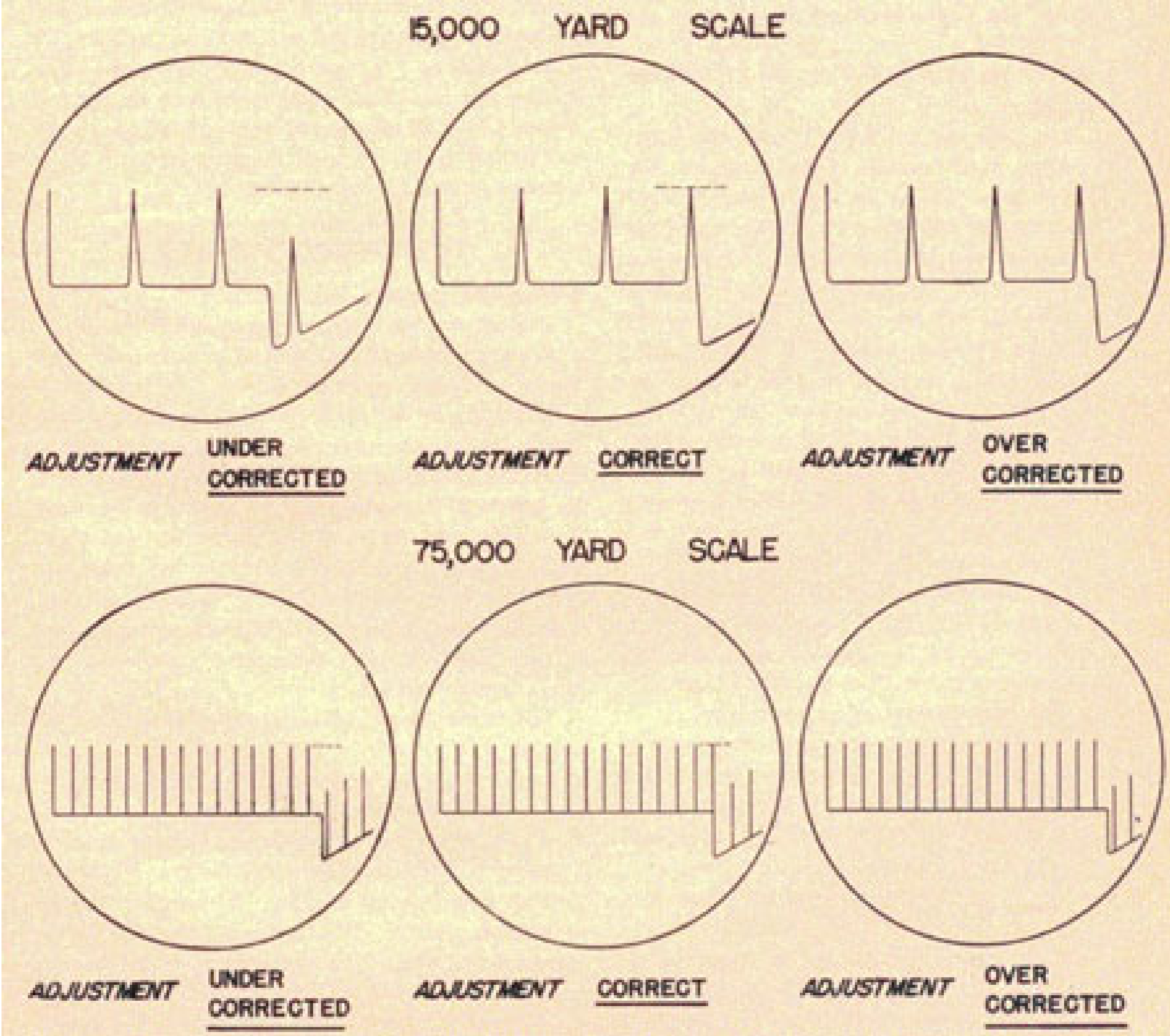

Figure 4 SG-2. Correct calibration at 15,000- and 75,000-yard ranges scales.

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be visible at the left end of the time base. However, there should not be any confusion as to whether the first visible marker represents zero or 5,000 yards. If the zero marker appears, it will just he seen at the extreme left end of the time base. lithe first visible marker is some distance from the beginning of the time base, it is the 5,000-yard marker.

The step is first lined up with the center of the 5,000-yard marker, and the range counters should read exactly 5,000 yards. Next, the step is cranked until the 75,000-yard marker begins to drop down. The counters should read exactly 75,000 yards. The 75,000-yard marker will be the sixteenth or

by comparison with fire-control radar, by ranging on some target whose distance can he determined precisely, or by observation of a *double range echo*. A double range echo is a false echo that will sometimes appear on the same bearing as a target, but at twice the range of that target. These echoes are most evident when the target ship is on a parallel course, close abeam, and large. If the real echo appears at 800 yards and the double range echo appears at 1,800 yards, the correct range of the target will he the difference between the two, or 1,000 yards. Since, in this example, your radar measured the range as 800 yards, the set's individual, constant error would be 200 yards, making all ranges low by that amount.

fifteenth, depending on whether the zero marker is, or is not visible.

If the calibration of the range counters is not correct, the operator will perform the following operations:

1. Turn the signal-markers switch (Q) to MARKERS.

2. Set the range switch (P) to the 15,000-yard position.

3. Turn the range crank (N) until the range counter reads exactly 15,000 yards on the lower scale. Unlock the 15,000-yard limit set control (3), and adjust it until the top of the fourth range marker at the far right just begins to "pull down" into the step. Lock the control in this position.

4. Change the range switch (P) to the 75,000yard position. If the range crank has not been move], the top counter will read 75,000 yards. Unlock the 75,000-yard limit set control (5), and turn it until the 75,000-yard marker (fifteenth or sixteenth from the left) begins to "pull down" into the step. Then lock the control again.

5. Turn the range crank (N) until the top counter reads 5,000. Unlock the 75,000-yard zero set control (4), and adjust it until the 5,000-yard marker (first or second from the left) begins to drop. Lock the control.

6. Switch to the 15.000-yard range, and turn the range crank until the bottom counters read 5,000. Now unlock the 15,000-yard zero set control (2) and adjust it until the 5,000-yard marker begins to drop. Lock the control.

Be sure the set has been warmed up and calibrated carefully before trying to determine its error. When determined, the error can be compensated in calibration. Thus, to compensate for the error in the above example, set the range dial to 5,200 yards, and 15,200 yards instead of 5,000 yards and 15,000 yards,-line up the first and third range marks with the step as before. Now all ranges read on the 15,000-yard scale will he 200 yards higher and therefore correct. Make the same compensation on 75,000-yard scale.

OPERATIONAL TECHNIQUE

Tuning the receiver.

The operator has only one tuning control to adjust. This control is the knob marked receiver-tune (M) located next to the range crank.

When the set is turned on from the stand-by condition, it takes about twenty minutes for the oscillator frequency to become stable. The tuning will have to be adjusted frequently if the set is to be used during this first 20 minutes. After this "warm-up" time the tuning will be fairly stable, but should be checked at least every half hour, or by each new operator. Experience will indicate how often your particular set must he tuned. Some sets require more frequent tuning than others.

The following procedures are used to tune the receiver:

Land echo. The best method is to tune on a land echo. Stop the antenna in order to get a good steady land echo on the "A" scope. Turn the gain down to where the echo is not saturated (to where it is about half of its maximum height). Then adjust the receiver-tune control (M) until the signal is at its maximum height. The technique for determining maximum signal height is to turn the tuning control

7. Re-check the upper limits on both range scales.

External calibration.

It is important that the external calibration of the set he checked periodically. This may be done by using one of three methods. It may be determined rapidly when approaching the maximum height, going a little beyond and a little under maximum signal, and

then estimating the mean (average) setting between these two points. During tuning, always keep the signal below saturation by adjusting the receiver gain control (L), and make the setting rapidly.

Ship echo. The next method is similar to the foregoing but is not so effective. Tune on an echo from another ship. The same procedure is used; however, trouble will be experienced because the echo will bounce up and down. Tuning on an echo of this type requires a certain amount of skill and experience.

Sea-return. Another method, which, under certain conditions such as especially heavy weather is better than tuning on ship echoes, is to tune for maximum sea-return.

The sea-return consists of many bouncing echoes which extend out, sometimes as far as 6,000 yards. The operator should operate the set on the short-range scale, watch the "A" scope, and tune for the point where overall sea-return is highest and extends out to the greatest range. An illustration of how sea-return should appear is shown in figure 4 SG-3.

Meter. If there are no echoes or sea-return available for tuning, throw the receiver tune-normal-monitor switch (M) to the RECEIVER search should use both the "A" and PPI scopes, with the following procedure:

Switch to the 75,000-yard scale and adjust the receiver gain for about 3/8-inch of grass on the "A" scope. Then, for approximately five minutes, search with the antenna on automatic rotation at the slowest speed. The operator should watch the PPI for two antenna sweeps, then the "A" scope for two sweeps, then the PPI for two more, and so on for the rest of the five minutes. At the end of this time, switch to hand rotation and make a slow hand rotation of a full 360 degrees, watching the "A" scope very carefully. After this, repeat the automatic rotation search.

The speed used for automatic rotation is 4 rpm in the first position. Some ships have changed this so that the first position now has an antenna rotation speed of 1 or 2 rpm. If the set aboard your ship does not have a rotation as slow as this, the technician can easily change it to the desired speed. When this adjustment has been made, the operator can use the second speed of rotation, 4 rpm, for normal search, and lie can use the first speed in place of the hand search.

Close-range search or small target search.

This type of search is primarily intended to detect surfaced submarines, periscopes, or PT boats,

TUNE position. Then tune for the highest reading on the transmitter current meter (C), using the receiver tune (M) control. Do not fail to return switch to NORMAL after tuning, since in receiver tune position, ranges will be 500 yards off.

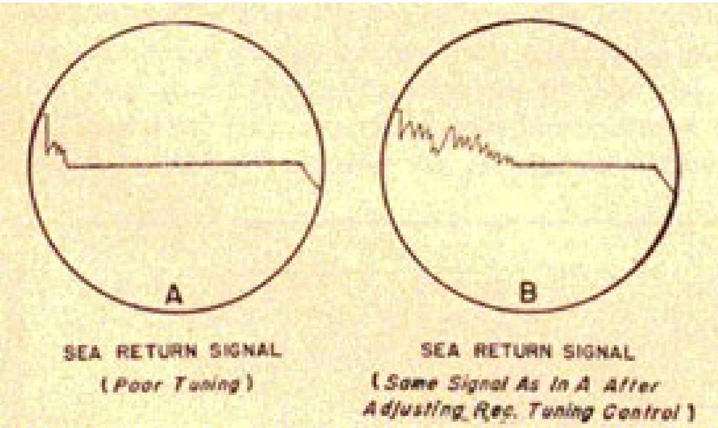

Fig. 4 SG-3. Sea-return on the "A" scope using 15,000 yard range scale.

Long-range search or large target search.

The "A" scope will show targets at greater ranges than the PPI; therefore, it is necessary that the "A" scope he used in the long-range search. The PPI is, however, much easier to watch, and once a target appears on it, there will he little chance of the operator missing the echo.

Because of the above considerations, a long-range although it has other functions. The following procedure should he used.

Switch the range to the 15,000-yard scale. The search is conducted by watching the PPI scope, using an antenna speed of 1 or 2 rpm, (or 4 rpm if that is the slowest available).

Two conditions requiring special attention are likely to be encountered in this type of search. The first is sea-return, which may extend to 1,000 or 2,000 yards, and in rough weather to 6,000 yards. With the receiver gain up to its normal value, targets at close range will be hidden in this sea-return. To detect, or to get bearings and ranges on targets under these conditions, it is necessary to reduce receiver gain. It should be borne in mind, however, that the gain is reduced only when checking these close targets, and then only for a very short time, since the gain must be up if the small echoes from submarines are to be detected.

The other thing requiring consideration on this range is the *saturated echo*. Targets at such short ranges give strong echoes. On the "A" scope these echoes are saturated; that is, they have flat tops. To get an accurate range on this type echo, the range dial should be cranked to a point at which one-half of the

flat top drops off into the step. The illustration in figure 4 SG-4 shows the correct means of ranging on a saturated pip.

To get an accurate bearing on these strong echoes, the PPI should be used. Rapidly rotate the antenna back and forth so that the entire echo is visible on the PPI; then quickly stop the antenna so as to bisect the echo.

Station keeping.

For station keeping, it is not usually necessary to obtain extremely accurate ranges and bearings. In normal steaming, ranges and bearings to the guide ship may he obtained with sufficient accuracy for keeping station without stopping the antenna rotation. The PPI scope is used to approximate the bearing. The bearing is read off the scale surrounding the PPI by mentally drawing a line from the PPI center through the target to the scale. The range may be approximated by several different methods. The best method is to mark permanent 5,000-yard circles on the PPI with India ink-, and to estimate range in relation to these. A second method is to switch the signal-markers switch to MARKERS. As the antenna rotates, 5,000-yard circles will remain for a few seconds after the switch is turned back to SIGNALS. The range to the target may be estimated by noting its position relative to the marker circles. The third method is to put a piece of scotch tape on the "A" scope and ink a scale of ranges on it. Then, as the antenna sweeps by the target, the operator watches for the pip to jump up on the range scope and obtains the range from the scotch tape. A new rotating scale device is being placed on the PPI's of many of the SC's in the Elect. The range and bearing of target may be estimated by simply rotating the scale to coincide with the target. This device has two disadvantages: first, the range scale is inaccurate; second, it obscures the view of the PPI. A more satisfactory device is under development.

The above-mentioned methods of approximations are usually satisfactory for normal station keeping. While taking a new station, or during formation changes, it will usually be necessary to get accurate ranges and bearings in the normal way.

Radar was not meant to supersede regular station keeping methods. Since such use cuts down the search efficiency, employment of radar for station keeping should be kept to the absolute minimum.

Auxiliary fire control.

The SG may he called upon for fire-control work, especially torpedo fire-control on destroyers. There is always the possibility that the fire-control radars may be put out of commission, making it necessary to use the SG to obtain accurate bearings and ranges to be used in the computers. This can best be done by stopping the antenna. However, since such procedure cuts down the efficiency of the search, tracking should be carried on without stopping the antenna unless accuracy is absolutely vital. It is recommended that at least one 360 degree sweep be made per minute while tracking, to guard against surprise.

Shell splashes can be picked up when the antenna is trained in the direction of fire. On the "A" scope the echo will jump up rapidly, and a quick estimation of range difference between it aid the target echo may he made. If the antenna is rapidly rotated back and forth by hand so as to cover a small sector near the target, the splashes may appear on the PPI. It is

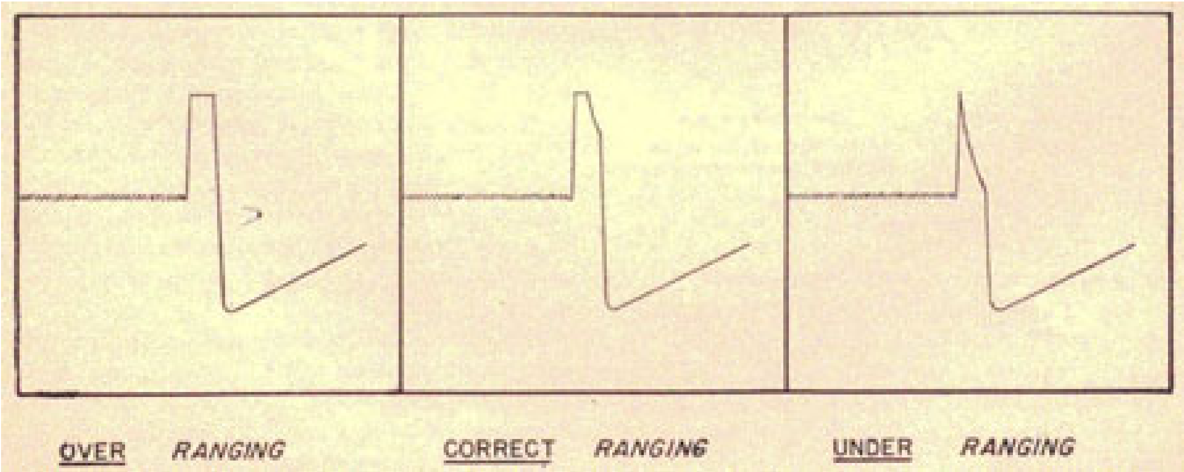

Figure 4 SG-4 Correct method for ranging on a saturated signal on the 15,000-yard range scale.

4-SG-8

SG RADAR

possible to do very rough spotting in both range and deflection by estimation from the PPI.

Navigation.

The SG is extremely useful to the navigator, particularly when operating in close waters. The navigator who is always cognizant of the ship's position will he able to give the operator the approximate bearing, distance, and expected time of contact with land. From his chart lie will be able to tell if the land rises abruptly out of the water, or, in case the land is low lying near the beach, whether or not it rises farther inland.

Land that rises at the water's edge to considerable height is excellent for radar purposes since the closest land appearing on the PPI in this case, is usually the beach. The chart should always be checked for the possibility of inland mountains appearing; first, by checking the altitude of mountain peaks against the altitude of the shore line, and second, by checking the outline of the shore from the chart against the outline from the PPI. In eases of this type of land, the outlines will be almost identical, and comparison with the chart may be used to fix the ship's position.

hounded by coral reefs and shoals, so extreme caution must be observed while using radar navigational fix taken close to them. Lack of small prominent points on these islands makes it difficult to obtain reliable fixes.

Sometimes it is possible to detect shoals on the radar screens, if the shoals are close enough to the surface to cause a disturbance in the water. The signal appearing on the radar screen would be much the same as a "wake" signal obtained from another ship. However, shoals are very treacherous and ships should not rely upon radar to detect them.

Composition.

When a contact is detected on the SG, it is extremely important that certain facts be determined about its composition. Ability to obtain these facts comes largely from experience, but the following hints may be of value.

Type and number of ships. The range of initial contact is the best indication of target size. Fixed antenna height results in ships of a certain size usually having a certain maximum range. Thus, on a ship where it is usual to contact battleships at 40,000

Almost all the islands in the Aleutians are of this type.

Another type of situation involves a low-lying shore line and inland mountains. When contact is first made, only the mountains will appear on the PPI, since the low shore will be below the horizon. With this type of land it would be a dangerous mistake to assume that the beach is the closest contact. Failure to remember this may result in the ship's grounding. For this same reason, unless your knowledge of the contour of the land justifies it, *never* depend on bearing tangents for fixing your position.

The best fixes are not necessarily obtained from a large group of random ranges and bearings, or from the closest land. The best method is to obtain a few accurate ranges and bearings of small prominent objects. Isolated rocks, small distinct islands, and isolated mountain peaks are excellent for obtaining fixes. The prominent points may be chosen from the chart. If the ranges and bearings obtained on two or three of them plot in at the same point, it is safe to assume that that point is your position.

Always remember to make use of the contours of the land when employing radar for navigation. By closely examining the echo of the "A" scope for multiple peaks and other peculiarities, the echo may be more definitely fixed to some position on the chart.

Islands in the mid-Pacific are very flat, and rise only a few feet above sea level. These islands are usually

yards and destroyers at 25,000 yards, first contact at 38,000 yards would indicate a ship of battleship size.

Echoes from large ships will he much steadier than those from small ships, and will usually appear thicker on the "A" scope. On first contact or at great distance, the "A" scope should be used for determining the number of ships in a contacted group. Turn the receiver gain down, and examine the top of the echo for multiple peaks, counting as many as possible. It should be remembered that when contact is first made, only the large ships will appear, since the smaller ones will still be out of range.

Aircraft. Pips from aircraft will appear quite erratic, the echo fluctuating rapidly on the "A" scope. On the PPI they are apt to appear very strongly on the antenna sweep, be absent on the next sweep, and appear at some other position on the next sweep. They may be recognized by their fluctuating echo and rapid change of position.

Land. Land echoes are steady and are likely to be quite wide. When plotted on the DRT, their position will remain stationary.

False echoes. Various types of false echoes are encountered with the SG. They are not caused by trouble in the equipment, and are not truly false for they are actually caused by some reflecting surface. They are, however, considered false because they indicate objects in which we are not interested.

Multiple-reflection echoes are caused by the beam reflecting between several ships in a group before returning to the antenna. The bearing of the echo will be the same as one of the ships. Because of the changing position of the ships, this type of echo will disappear very quickly.

In close formations, double-range echoes are quite common. They are caused by the returning echo reflecting off the searching ship, again reflecting off the target, and finally reaching the antenna. This type of false echo may be recognized by three factors; first, it will always be at the same bearing as one of the large targets; second, it will be at exactly twice the range of the large targets; and third, it will vary rapidly in amplitude.

Second-sweep echoes result from long-range echoes arriving back after the next sweep has started. With a pulse rate of 1,000 c.p.s., there is time for 81 miles of range between each pulse and sweep. Thus, for an echo to appear on the second sweep it must be over 81 miles away. Trouble will be experienced with this type of echo only when there is high land over 81 miles away. In order to know when second-sweep echoes are likely to be encountered, the operator should be constantly aware of the ship's position in relation to land. To check this type of false echo, the pulse rate should be changed. If the echo is of the second-sweep type, it will shift in range or disappear entirely. Although these echoes are rare, they should be recognized and understood. Figure 4 SG-5 shows a graphic representation of how the second-sweep echo pip will shift its position on the "A" scope as the pulse frequency is varied.

Another type of false echo results from reflection off some part of the ships structure. These echoes occur when the mast or superstructure is in the path of the radiated beam. The energy reflects off the interfering structure, hits the target, and returns by the same route. The false echo will be at the same range as some real target and on the bearing of the

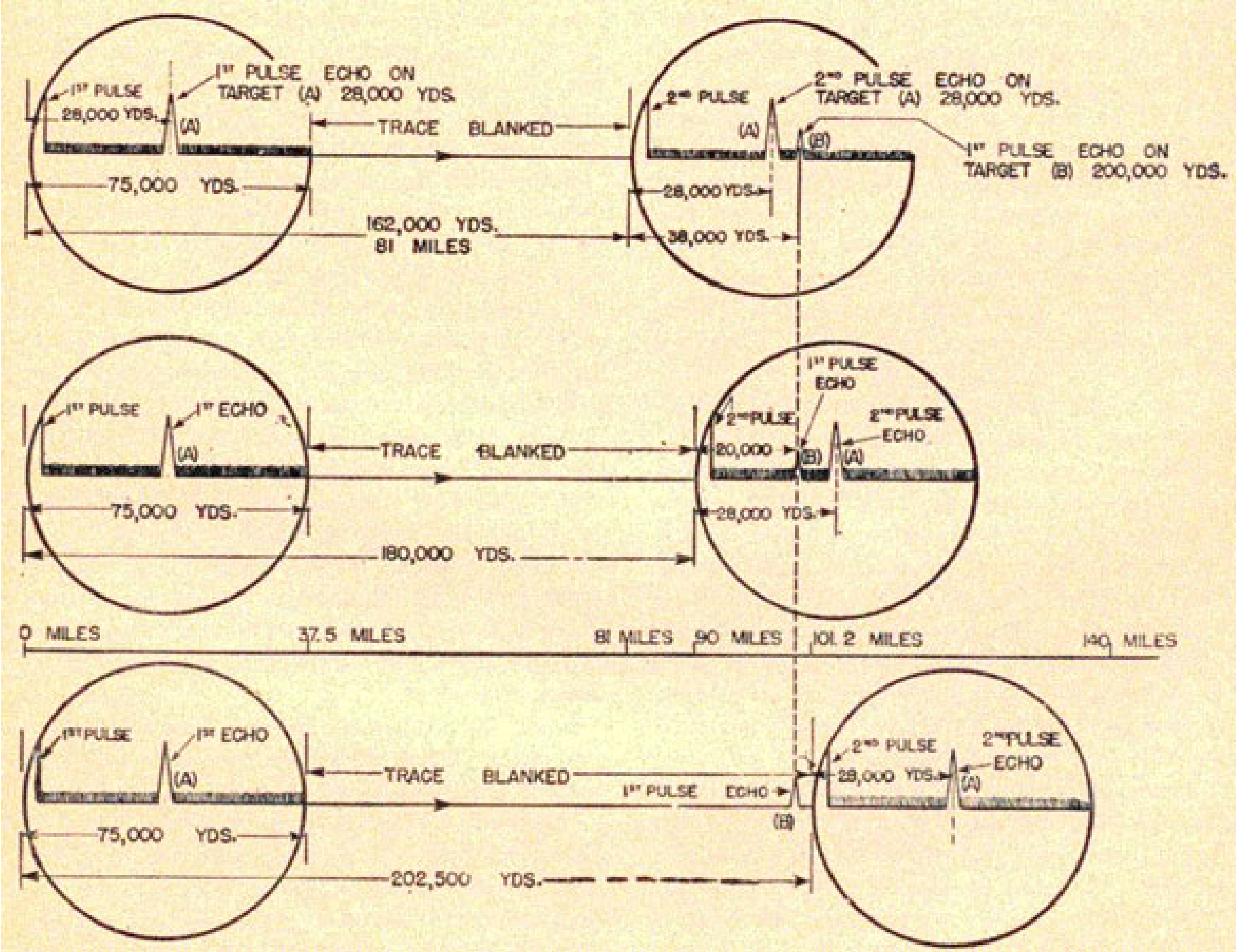

Figure 4 SG-5. Second-sweep echoes.

4-SG-10

SG RADAR

interfering structure. The SG also has side lobes 60 degrees to 70 degrees on either side of the main lobe. They will often show up on a large target which is within 5,000 yards.

PPI echoes. When cruising in close formation with other ships, the picture that appears on the PPI will give the impression that we can determine the course of each individual ship simply by observing the PPI. This is definitely not true; although all the ships are on a similar course, each appears on the PPI to be on a different one because of the curved pip resulting from the radial sweep.

Jamming and deception.

There is no doubt that the enemy considers our radar an extremely dangerous weapon, and consequently it is only reasonable to expect him to try every means possible to make it less effective. He may use two tactics to do this: jamming and/or deception. Every operator should learn how to recognize these countermeasures, and expect them when in combat zones.

When the enemy broadcasts radio signals intending that our radar receive them, and they show a confusing pattern on the screen, it is called *jamming*. Use of dummy targets (tinfoil, kites, balloons, etc.) is called *deception*. More precise definitions are sometimes given, but these are satisfactory for this discussion.

The SG radar can be jammed, and it will show echoes from the tinfoil the enemy sometimes throws out to confuse the operator. The operator should not become alarmed when either of these things happen.

If you were suddenly confronted with jamming without previous experience, it would appear impossible to work through. However, it is not always be on some certain relative bearing regardless of own-ships course changes.

Try moving the gain control up and down. This is probably one of the most important countermeasures that can be taken, and the one most commonly overlooked because of its simplicity.

In most cases, except when effective noise modulated jamming is being encountered, there is a setting of the gain control with which it is possible to range on a target in the presence of heavy jamming. If there are several echoes on the same bearing, the best setting for each echo is different. Of course it is more difficult to obtain these ranges because of the distortion of the echo produced by jamming, but it is, after all, possible to obtain the desired information. The extra effort is worth while because the enemy would not be jamming unless he were trying to conceal something important.

Two general methods of using the gain control, both of which should be tried, are as follows:

1. Reduce setting; this prevents overload of radar receiver; echoes are visible "riding on top" of the jamming pattern.

2. Increase setting; this limits (or clips) jamming; echoes are visible as a break in the base line.

Try changing receiver local oscillator tuning. When you change the rec. tune, you lose some of the height of the desired echo. However, if the jammer is not exactly on your radar frequency, there is a chance that you will detune the jamming signal more than the echo signal. Considerable improvement can sometimes be obtained in this way. Try "swinging" the rec. tune dial in both directions to see which direction brings the greatest improvement. Note the correct setting of the rec. tune dial so that it can be returned to its normal

really that serious if the following procedure is carried out:

1. DF on the jamming.

2. Use available anti-jamming devices on receiver when provided.

3. Try moving the gain control up and down.

4. Try changing the receiver local oscillator tuning.

5. Keep operating.

6. Report the type and bearing of jamming to CIC.

The first reason for obtaining a bearing on the jamming is to determine whether or not it could be accidental interference. Jamming will not only be directional, but its true bearing will not be changed by any sudden change in your ship's course. Interference originating aboard your own ship will either be non-directional and appear on all bearings, or else it will position when no jam is present, or if detuning does not help.

Keep operating. Even if the jamming is extremely effective, keep trying and do not turn your radar off. Turning your radar off informs the enemy that his jamming is effective, and certainly makes the radar completely worthless. The effectiveness of the jamming may change from time to time, so if you are persistent enough some information may be obtainable.

Report the nature and bearing of jamming to CIC. Recognizing the type may be difficult because nonsynchronous patterns sometimes appear blurred beyond recognition. Inasmuch as knowledge of jamming type * may possibly help identify the jammer

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* See Part 3, Defense Against Jamming and Deception.

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in some cases, this information should he reported if possible. If the equipment is provided with an anti-jamming receiver, the jamming may be reduced sufficiently for reading targets without any detuning of the receiver. Detuning should be undertaken as a last resort, and then should be done very carefully and cautiously; otherwise all targets may be lost and the procedure made completely ineffective. No special method is offered for setting the controls of the AJ receiver, except that they should be varied for minimum jamming, the gain control coming first, and then the A\TC control.

Above all, never turn off the radar.

When jamming and/or deception is encountered, full 360 degree search must be continued. However, the antenna should be stopped for short intervals from time to time, in order to try reading through the jamming (using the "A" scope). You also must be prepared for any diversionary tactics, for the enemy may or may not use jamming and/or deception to divert your attention from the bearing of the main attacking forces. This problem is simplified somewhat when similar but separate radars are used for reading through jamming and for searching.

PERFORMANCE

Maximum reliable range.

Ranges in surface craft obtained with the SG are dependent on the antenna height. Expected ranges with a typical antenna height should he of value to the new operator.

The results listed below are maximum reliable ranges for a 90-foot antenna.

Accuracy.

Range accuracy is +/- 150 yards.

Bearing accuracy is +/- 1 degree.

Resolution.

Assuming two targets to be on the same bearing, the SG can distinguish between them at short ranges when they are separated by no more than 300 yards; at longer ranges approximately 500 yards separation is needed. At any range, too high gain tends to cause the pips to merge, and reduces discriminatory power. In general, the SG is able to discriminate in range between two targets separated by 300 yards or more on the "A" scope, and 500 yards on the PPI.

With respect to bearing, a comparable minimum limit exists and is expressed in angular rather than linear measurement. Since the transmitted beam does not travel along a single line, but has an angular spread, it can be seen that if there are two targets at the same range, one in the center of the beam pattern and the other in the edge, an echo will be returned from the target in the center and from the target in the edge, and these will appear as one echo. By reducing receiver gain it will often be possible to distinguish both targets. At normal ranges the angular separation necessary for target discrimination in bearing is 5 degrees using the "A" scope, and 9 degrees using the PPI.

TROUBLES

Major troubles are handled by the technicians but time will be saved if the operator is able to recognize some of the minor breakdowns.

If the sweep traces on the "A" and PPI scopes suddenly go out, the indicator fuse next to the "A" scope should be checked,

Type of target.	*SG*	*SG-A and SG-1*
BB, CV, Large auxiliaries	35,000-45,000 yards	45,000-55,000 yards
CA, CL, Medium auxiliaries	28,000-35,000 yards	30,000-40,000 yards
DD, DM, AV, PC	18,000-30,000 yards	25,000-35,000 yards
Submarines	9,000-12,000 yards	11,000-15,000 yards
Submarine periscope	2,000-4,000 yards	2,000- 4,000 yards
Large planes (altitude 1000'-3000') PBM, PBY, PBZ	20,000-35,000 yards	20,000-40,000 yards
Small planes (altitude 1000'-3000') SOC, OSZU, SBD, F4F	10,000-15,000 yards	12,000-21,000 yards

Minimum range.	*SG*	*SG-A and SG-1*
Ship	600 yards	600 yards
Plane	1,000 yards	1,200 yards

4-SG-12

SG RADAR

If the antenna and "bug" will not turn when the antenna is switched to automatic rotation, the bearing fuse next to the "A" scope should be checked.

If the red light goes out, sweeps disappear, and the plate current drops to zero, the overload relay probably has kicked out. Torn the high-voltage variac all the way down, press the overload reset, wait for the red light to come on, and then turn up the variac to the proper value.

When ranges appear to be 500 yards too high, the receiver-tune- normal monitor switch should be checked to see if it is on NORMAL position.

If the sweeps on either scope appear fuzzy, their respective focus controls should be adjusted.

There are certain occurrences which are entirely normal on the SG but which might be interpreted as troubles by the new operator.

as a series of markers described through 360 degrees. When this condition exists, the operator should do the following:

1. Shift the switch on the gyro-control panel from the forward gyro to the after gyro supply or vice versa.

2. If this does not correct the situation, shift the synchro switch on the R and T indicator from NORMAL to EMERGENCY and continue to operate, reading relative bearing only on the outer dial.

If the synchro excitation should fail while at sea, and there are no targets on the screen, it will be difficult to detect what is wrong. The operator might detect the trouble by close observation of the "A" scope for changes in sea-return signals. If there seem to be no changes in the signals the operator should have someone cheek visually to see if the antenna is rotating.

If the synchro excitation to the antenna control motor should fail, the operator will be able to detect the trouble almost immediately. When the synchro supply goes out, the antenna will stop rotating, even though the "bug" continues to rotate and the sweep continues on the PPI. However, the picture on the "A" scope will stay constant because the antenna is not rotating, and the picture on the PPI will appear

Sometimes targets will be obscured by radar interference. This appears as either a series of dots, or as a series of radial lines on the PPI. There is not much that can be done to correct the situation: however, changing the pulse rate sometimes changes the interference pattern so as to make it less objectionable. When interference is severe, use the "A" scope.

4-SG-13

PART 4

SC-SK RADAR

4-SC/SK-1

RADAR OPERATOR'S MANUAL
SC-SK RADAR

The SC radar is now obsolete and will not be dealt with in this discussion. The controls on the control unit and the receiver indicator unit, which the operator uses, are the same as those of the SC-1. The SC-1 radar is a modification of the SC. The transmitter was re-designed to increase the power output, and the antenna was modified. A preamplifier unit has been added to most sets.

The SC-2 radar is similar to the SC-1, but incorporates a few modifications. The sweep circuit has been revised, and the antenna has been re-designed, with a directional IFF antenna included. A PPI unit has also been added. The SK radar at present is an SC-2 with an antenna four times as large. The SC-2 or SK radars are composed of six units, as follows:

6. The antenna, together with transmission line and duplexer units.

The operator is concerned principally with the first two units, and possibly with the fourth, and the duplexer unit of the sixth. Ordinarily, the technician tunes the transmitter, preamplifier, duplexer, and receiver. The operator checks the tuning of the receiver at the beginning of his watch.

CONTROLS

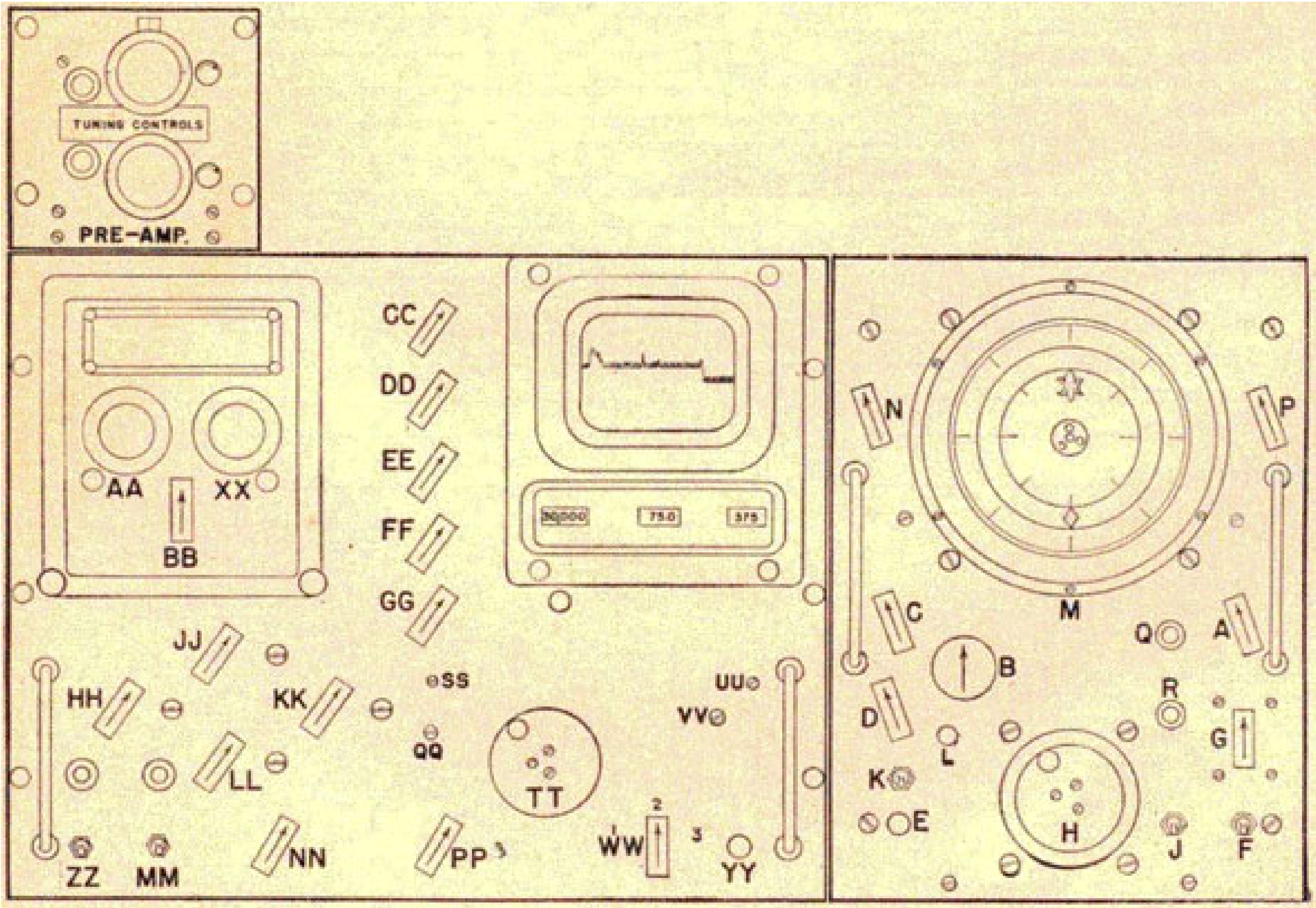
Control unit.

A. *Main power switch*: controls power to all units.

B. *Transmitter-plate voltage*: this switch, when snapped on, applies all power to the transmitter. As it is turned clockwise, it increases the high voltage applied to the transmitter tubes.

1. The control unit.
2. The receiver indicator unit.
3. The transmitter.
4. The preamplifier.
5. The plan position Indicator unit.

C. *Relative-true bearing switch*: when on TRUE the antenna is controlled by the ship's gyro system. Relative bearings are read on the outer dial, and true bearings on the inner dial of bearing indicator (M). When on RELATIVE, the antenna is controlled by power from the set. This maintains antenna control in the event that gyro power fails. Only relative bearings to the outer dial may then be read.



Drawing of receiver, indicator and control unit front panel.

4-SC/SK-2

SC-SK RADAR

D. *Remote bearing indicator switch*: applies control power to remote bearing repeaters.

E. *Remote bearing mark*: buzzer or horn switch to notify remote station when readings may be taken.

F. *Automatic-manual toggle switch*: power switch to slewing motor, which gives automatic antenna rotation.

G. *Antenna-control switch*: center position is off. Right gives clockwise rotation. Left gives counterclockwise rotation. Speed is controlled by the amount of turning.

H. *Hand crank*: for antenna control.

J. *BL power switch*; may or may not be used.

K. *Sweep*: local-PH; PPI position used when in sector search. Local position is the normal operating position.

L. *Overload relay reset*.

M. *Bearing indicator*: inner dial-true; outer dial-relative.

N. *Brightness control* of bearing indicator light.

P. *Brightness control* of pilot lights.

Q. *Transmitter pilot light*.

R. *BL power pilot light*.

Receiver unit.

AA. *Radio frequency tuning control*.

XX. *Local oscillator tuning control*.

DD. *Dial light brightness control*: controls brightness of the pilot lights and range-counter lights on the indicator unit.

EE. *Brilliance control*: controls brightness of the trace.

FF. *Focus control*: controls width of the trace.

GG. *Astigmatism control*: controls uniformity of focus along length of the sweep.

HH. *IFF gain control*.

JJ. *Calibrate maximum*.

KK. *Calibrate frequency*.

LL. *Calibrate minimum*.

MM. *Challenge switch for IFF*: puts the IFF system into operation from standby.

NN. *Synchronizing switch*: EXTERNAL-INTELNAL: normal operating position on EXTERNAL. Brings synchronizing pulse from transmitter to the indicator. INTERNAL position may be used for adjusting sweep and calibrating frequency when high voltage has not been turned up.

PP. *Crystal switch*.

QQ. *Range step height control*.

SS. *Vertical trace centering control*.

TT. *Range crank*.

UU. *Horizontal sweep centering control*.

VV. *Synchronizing pulse gain control*.

BB. *Receiver gain control*.

Indicator unit.

CC. *Receive-calibrate switch*.

WW. *Range selector switch*:

Range 1-30,000 yards
Range 2-75 miles
Range 3-375 miles

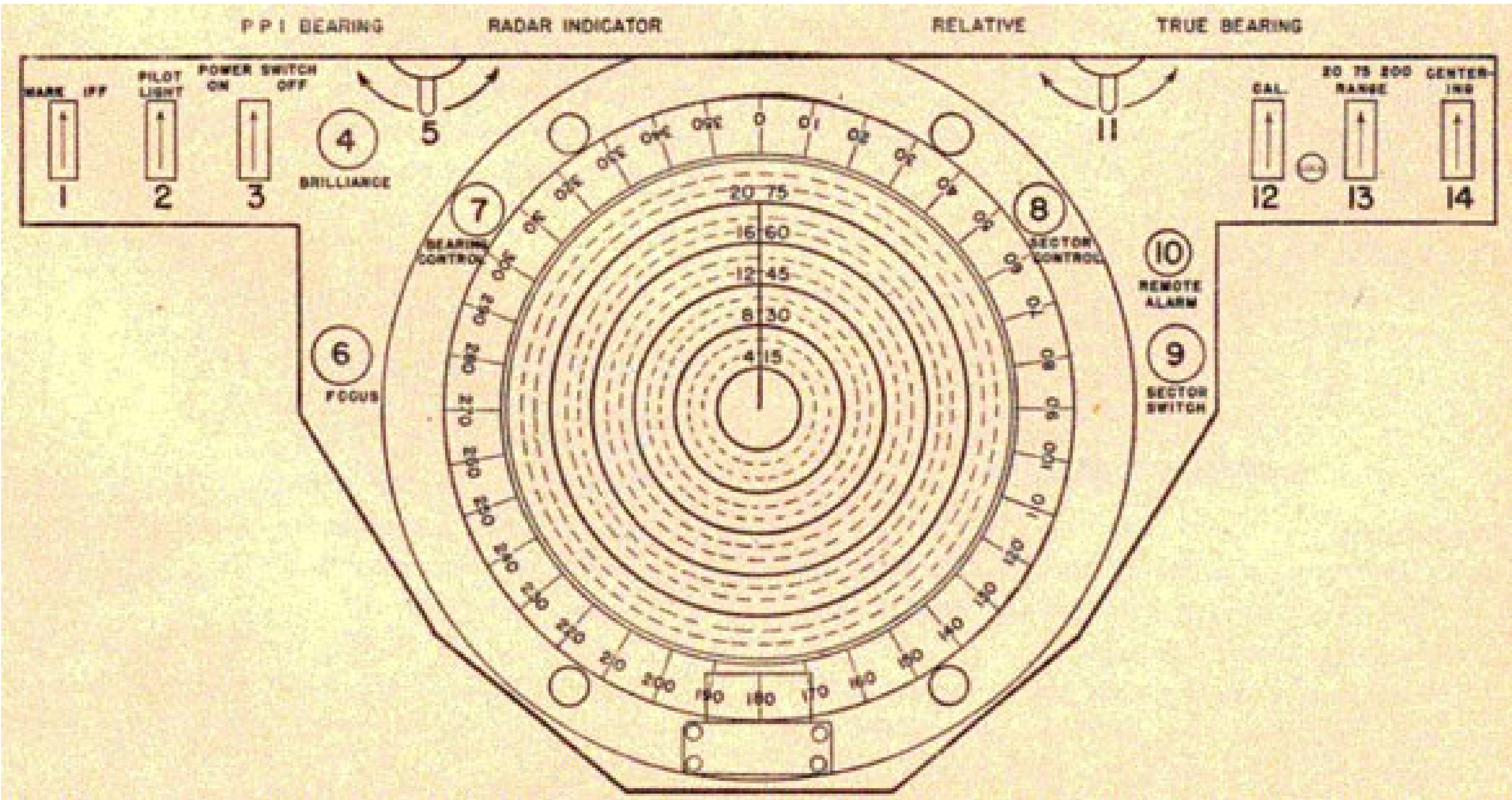


Figure 4 SC/SK-2. Plan position indicator.

VV. *Remote range mark*: remote alarm switch,

ZZ. *Power switch for receiver indicator unit*.

PPI unit.

1. *Mark-IFF switch*: normal operating position on IFF. When on MARK, range step is shown on PPI.

2. *Dimmer control* for PPI bearing dial light.

3. *PPI power switch*.

3. Turn ON receiver indicator power switch (ZZ). Pilot light (RR) and the lights on the range counter will light. After a few seconds, a trace will be seen on the range scope, unless the brilliance control (EE) is fully counterclockwise.

4. Turn ON the power switch of the PPI unit. The lamp for the bearing glass will light.

5. After waiting a half minute, the filaments of the transmitter tubes will be hot, and the plate voltage variac (B) should be turned slowly up to between 70 and 100. This value is determined by the technician.

4. *Brilliance control*.

5. *Bearing indicator switch*; RADAR-PPI: when on RADAR, bug follows the antenna; when on PPI, bug follows the yoke (cursor).

6. *Focus control*. 7. *Bearing indicator adjustment control*: for synchronizing bug reading and cursor reading, when operating bearing indicator switch is in the PPI position. Depress knob and set cursor (bearing blade) to read with the bug, then release knob to again engage the cursor.

8. *Sector search control*: in normal position, which is DOWN, clockwise rotation of the control increases the sector. Counterclockwise rotation narrows the sector. When pulled UP to engage the cursor, the sector may be rotated by rotating the cursor.

9. *Sector search off-on switch*.

10. *Remote alarm button*.

11. *Relative-true switch for PPI*.

12. *Calibration control*.

13. *Range selector switch*:

Range 1-20 miles
Range 2-75 miles
Range 3-200 miles

14. *Centering control*: controls only centering of sweep along axis of sweep.

Preamplifier unit.

1. All controls on the *preamplifier unit* are tuning controls.

6. Turn on BL power switch (J).

7. Start the antenna rotating by setting switch (F) on AUTOMATIC, and switch (G) to give a slow rotation of the antenna.

8. Turn up PPI intensity control (4) until a trace appears.

9. Adjust focus (6) to get fine uniform trace.

10. Center sweep with control (14). This adjustment should be made so that the beginning of the sweep starts at the same point regardless of the bearing. That is, there is no overlap of the sweep and no open portion. If the center of the sweep is not at the center of the scope, the technician must make internal adjustments.

Turning off.

1. Turn down (CCW) PPI intensity control (4).
2. Turn off power switch for PPI unit.
3. Turn off BL power switch (J).
4. Turn off automatic switch (F).
5. Turn switch G to OFF position.
6. Turn off receiver indicator power switch (ZZ).
7. Tarn plate voltage variac fully CCW.
8. Turn off main power switch (A).

CALIBRATION

Calibrating the range scope.

1. Turn switch (CC) to CALIBRATE.

2. Turn switch (WW) to Range 1.

3. Adjust brilliance (FE), focus (FF), and astigmatism (GG) for a fine uniform trace. These controls interact one on the other, and must he adjusted together.

TURNING ON AND OFF

Turning on.

1. Turn the main power switch (A) ON. The dial light of the bearing indicator will light, and the amplidyne motor will start,

2. Turn the transmitter plate voltage variac to 10. The pilot light (R) will light up and the filaments in the transmitter oscillator and power supply will glow.

4. Turn crystal switch (PP) to ON. A "figure of eight" with the lower half clipped will now he observed on the "A" scope. If this figure is not observed:

5. Release lock and adjust (KK)-frequency

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calibration so that a stationary figure of eight is observed. Lock control. (See fig. 4 SC/SK-3.)

6. Turn crystal switch (PP) to OFF.

7. Crank (TT) so that 2,000 yards is observed on the first range counter.

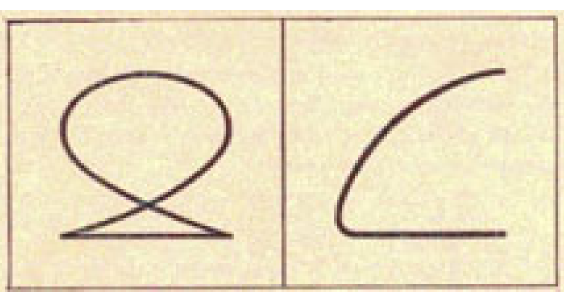

Figure 4 SC/SK-3. Figure of eight determines when calibration pips are 2,000 yards apart.

8. Release lock on calibrate minimum (LL) and adjust position of range step with (LL) so that the top of the second marker just begins to drop. (See fig. 4 SC/SK-4.)

9. Crank (TT) so that counter reads 20,000 yards.

10. Release lock and adjust calibrate maximum

13. Turn (CC) to RECEIVE. This method of calibration differs from that given in the instructional manual.
We use this method for three reasons:

a. To make the calibration and ranging uniform on SC-2 and SG, the center of the range mark and the center of the target pip are used.

b. It is easier to range on the center of a pip than on the leading edge.

c. This introduction of error compensates for a range error on SC radars when calibrated against fire-control radar.

Calibrating the PPI.

The PPI unit must never be calibrated until the "A" scope has been calibrated, since it is dependent on the accuracy of the calibration of the "A" scope.

1. Turn the mark-IFF switch (1) to MARK.

2. Set the range selector (WW) to Range 2, and set

(JJ) so that the top of the eleventh marker begins to drop.

11. Check the 2,000-yard setting and if it has changed, repeat step 9.

12. Check the 20,000-yard setting. If either (JJ) or (LL) is changed, it affects the other. Keep checking until no further adjustment is necessary; lock both controls.

the counter to 60 miles.

3. Set the PPI range selector (13) to Range 2.

4. With the antenna rotating rapidly, a circle will appear on the PPI scope. Set calibrate control (12) so that the inboard edge of the trace corresponds with the 60-mile ring on the scope face.

5. Set the range counter to 30 miles and check the calibration. If the internal calibration of the set is correct, the PPI will be calibrated for all three range scales.

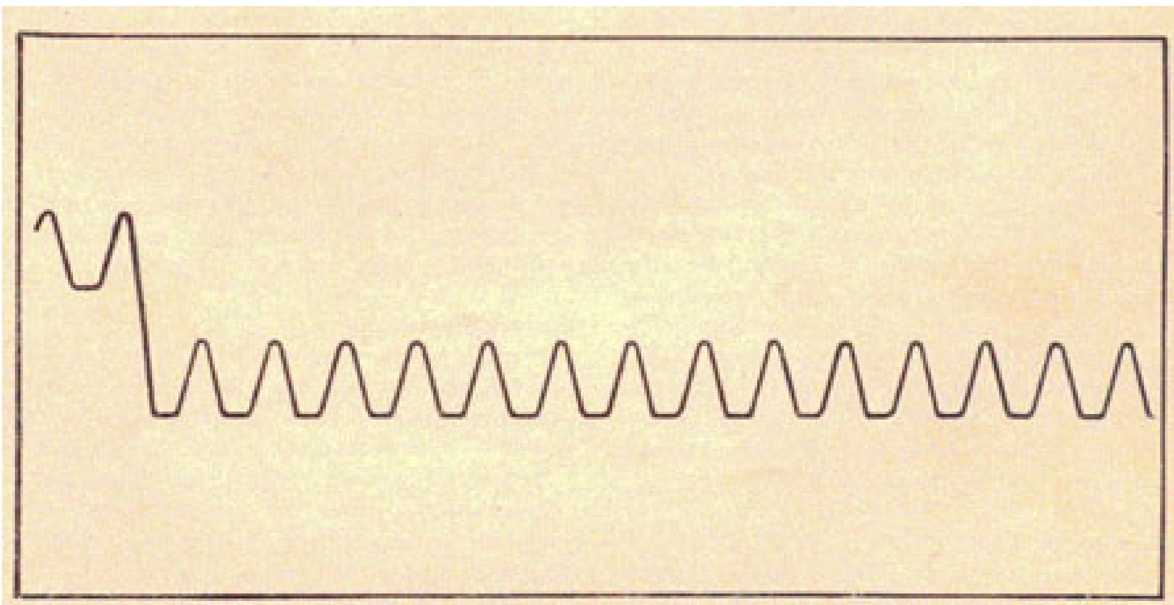

Figure 4 SC/SK-4. Pattern for calibrating minimum range on range 1.

Modification of PPI scope.

With the orange filter glass on the PPI, the range marks are so far from the screen that errors of several miles in range are possible because of parallax. The authorized revision should be made, whereby the filter glass is removed and the range lines made directly on the face of the PPI scope. This is (lone with a drafting compass and India ink as outlined below.

1. Make a center for the drafting compass out of a small piece of plastiglass in which you have drilled a shallow hole to hold the compass point.

2. Secure this center to the center of the PPI scope with scotch tape.

3. Using the radii of the range circles on the filter, ink solid circles on the scope face. To facilitate direct reading of the 75-mile range scale, ink in two dashed circles evenly spaced between the solid circles.

Direct reading of the PPI on the 75-mile range scale is now easy and accurate. The solid circles are 15 miles apart. The dashed circles are 5 miles apart. The range of any indication may he read accurately to the nearest mile. Bearings are read by bisecting the indication with the cursor, and reading the bearing on the illuminated indicator.

OPERATIONAL TECHNIQUE

Tuning the receiver.

The technician will have the transmitter tuned for maximum power output and it should not be touched by the operators.

The preamplifier and receiver are also tuned by all, or when there are one or more target indications on the screen which have been identified and are of interest to the CIC watch officer only, as to their general position. The CIC officer will get most of the information he desires from his repeater scope, but a rough plot should also he kept. Readings every three minutes are usually sufficient for this plot.

The range scale used on the scopes will depend on the tactical situation. In a carrier task force, initial contact at the longest range is highly desirable. Two methods of search are possible:

1. PPI scope on 200-mile range scale, and "A" scope on 75-mile range scale, or

2. PPI scope on 75-mile range scale, and "A" scope on 375-mile range scale.

When using the first method, most careful watch is made on the PPI scope with occasional search on the "A" scope. As the PPI is the less tiring scope to observe, most operators prefer this method.

The alternate method employs the closer watch of the "A" scope with occasional search on the PPI scope. The advantage of this method is that if a contact is made within 75 miles, tracking may be begun immediately on the PPI without changing scale.

If the task force has no air support, 75-mile warning of approaching aircraft is sufficient, and both scopes may be operated on the 75-mile range.

The receiver gain setting should he such as to give approximately 3/8-inch of grass on the range scope when the operator is giving his attention to the PPI scope. This should he reduced to between 1/16- and 1/8-inch when attention is given to the range scope.

The antenna should he rotated at a rate of

the technician, and only slight adjustments need he made by the operator. Care should be taken when tuning on a bobbing echo that increase in echo height results from tuning adjustments and not from bobbing of the echo. Tune for maximum results from tuning adjustments and not from bobbing of the echo. Tune for maximum echo height by going a little over and then a little under maximum. Jockey back and forth rapidly, and stop between the two points, a little over and a little under, for optimum tuning. If land echoes are available, they should be used for tuning. In any event, all operators should know the dial settings of the receiver for maximum echo height.

Long-range search.

Long-range search, so called, is essentially search for initial contacts at any range. It will he conducted either when there are no indications on the screen at approximately 1 1/2 revolutions per minute. A plot should be started on the first indication no matter how weak the signal. On the next sweep of the antenna, it may be stopped, the blip on the range scope studied to determine composition, and the plane challenged with IFF equipment. Normally this pause in continuous rotation should not take more than 15 seconds,

Searching over land.

If search must be made over land, target pips will be mixed with the land pips. However, planes will give echoes which bob up and down more rapidly and irregularly than the land pips. Also, the plane pip will move with respect to the land pips. When faced with the problem of searching over land, the antenna may he stopped for a few seconds to determine whether the pip is actually behaving as a plane echo or as a land echo. Bearings cannot be obtained very accurately, but the bearing of *maximum swing* of the

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pip should be reported. Land masses may cause the pip to be higher on a bearing a few degrees to one side of the actual target bearing, and so maximum pip height *may* not give the correct indication-it is the maximum bounce that counts. The approximate bearings secured are well worth the effort to get them.

The operator must remember to keep searching. He should *not* find one target and "camp on it" from then on.

Multiple-target tracking.

Multiple-target tracking should be done exclusively on the PPI. In the large majority of cases, the 75-mile scale is the proper scale for multiple-target tracking. Rapid ranges and the PPI should be operated on the 20-mile range. The gain should he reduced to an amount just sufficient to keep the targets at the longest ranges appearing on the scope. This will eliminate some side lobes and reduce strength on all side lobes while holding echoes from the main lobe on the screen. This method of operation eliminates any chance of observing planes coming in at ranges greater than 20 miles, but is the most effective method when the primary purpose is fire-control coaching. At GQ, the standby operator can keep the fighter director officer informed of the general situation outside 20 miles by observing the range scope and taking ranges and bearings with continuous antenna rotation.

When the set is operating so as to read true bearings on the PPI, only true bearings are put on a repeater.

bearings may be accurately obtained on targets at from 10 to 80 miles, and a good search for new targets at ranges up to 80 miles is maintained. The antenna rotation speed should be increased to 2 rpm, and half of the targets reported for each revolution. Gain setting should be for 3/8-inch of grass on the range scope. All ranges and bearings are read from the PP 1.

Fighter-director tracking.

To a good operator, there s no essential difference between multiple-target tracking and ID tracking. With the antenna rotating at 2 rpm, reports can be given on the intercept planes and bogies at 30-second intervals, by reporting these targets on every revolution of the antenna, if desired by the fighter director officer. A good track can be kept on all other targets by reporting them every other revolution, giving one minute reports to the plotter. Ranges and bearings should come directly from the PPI operating on the 75-mile range with the gain set for 3/8-inch of grass on the range scope.

It may happen in certain instances during night attacks, that the gunnery officer or assistant gunnery officer will want to man the PPI himself. He will then be in a position to direct AA fire rapidly, and the information will not be delayed by going through CIC and plotting.

Fire-control liaison.

Fire-control liaison may be conducted on the 75-mile range with normal gain setting at about ten miles, provided there are not many targets at the same range. With several targets on different bearings within ten miles, their echoes and side lobes will ring the PPI scope and cause too much confusion for fire-control coaching.

When the primary interest is fire-control coaching, If relative bearings are desired, the PPI *relative-true* switch can be thrown to RELATIVE, and the bearing indicator switch from RADAR to PPI. The bug is then adjusted to read the same on the outer dial as it is read on the yoke. Now, all bearings from the PPI will be relative, and the repeaters will read relative.

Composition.

Determination of composition of the target requires more operator experience and closer observation than any other phase of operation. Determination of composition involves use of IFF to determine whether a contact is friendly or not, and observation on both range and PPI scopes to determine number and size of planes in the group.

Large planes will have a low rate of fluctuation in echo amplitude, while small planes will have a high rate of fluctuation. The range scope is a better source of information on composition than the PPI scope. Upon making a contact, the antenna should he stopped on the target, the gain reduced to 1/16-inch grass on the "A" scope, and a thorough examination of the echo made. The number of planes can he estimated from the number of peaks on top of the echo. The range at which the target comes in is not conclusive proof of either its size or altitude, but is a major factor contributing to these estimations. The operator should give his estimate of the composition of every contact and this estimate should he substantiated or corrected by visual means whenever possible. The operator should then be notified of the exact number, size, formation, and altitude. Continuous repetition of this process is the only means of improving the operator's technique in determining composition.

Clouds, rain squalls, and ionized masses of air are readily detected on the "A" scope, and are usually easily disclosed on the PPI. Broad fuzzy pins, that

4-SC/SK-7

RADAR OPERATOR'S MANUAL

move slowly with occasional fading out, are characteristic of these targets, although sharp narrow pips have been observed. If identification is difficult by looking at the pip, a plot should be made to determine the course and speed. This should then be compared with the course and speed of the wind, which is the best check outside of actual observation.

Any operator will learn to recognize land readily. However, most of them, on looking at a group of pips from land, will call the highest pip the highest peak of land as "seen" by the radars. This is wrong. The highest pip will be from that part of the land which has the best reflecting surface. The peak will be hard to identify if there is a range of mountains behind it, or mountains in the near vicinity at about the same range.

Jamming and deception.

There is no doubt that the enemy considers our radar an extremely dangerous weapon, and consequently it is only reasonable to expect him to try every means possible to make it less effective. He may use two tactics to do this: jamming and/or deception. Every operator should learn how to recognize these countermeasures, and expect them when in combat zones.

When the enemy broadcasts radio signals intending that our radar receive them, and they show a confusing pattern on the screen, it is called *jamming*. Use of dummy targets (tinfoil, kites, balloons, etc.) is called *deception*. More precise definitions are sometimes given, but these are satisfactory for this discussion.

The SC radar can be jammed, and it will show accidental interference instead. Jamming will not only be directional, but its true hearing will not he changed by any sudden change in your ship's course. Interference originating aboard your own ship will either be non-directional and appear on all bearings, or else it will always be on some certain relative bearing regardless of changes in own ship's course.

Try moving the gain control up and down. This is probably one of the most important countermeasures that can he taken and the one most commonly overlooked because of its simplicity.

In most cases, except when effective noise modulated jamming is being encountered, there is a setting of the gain control with which it is possible to range on a target in the presence of heavy jamming. If there are several echoes on the same bearing, the best setting for each echo is different. Of course it is more difficult to obtain these ranges because of the distortion of the echo produced by jamming, but it is possible to obtain the desired information. The extra effort is worth while because the enemy would not be jamming unless he were trying to conceal something important.

Two general methods of using the gain control, both of which should be tried, are as follows:

a. Reduce setting; this prevents overload of the radar receiver; echoes are visible "riding on top" of the jamming pattern.

b. Increase setting; this limits (or clips) jamming; echoes are visible as a break in the base line.

Be sure to return the gain control to its normal setting when no jamming is present, or when the

echoes from the tinfoil the enemy sometimes throws out to confuse the operator. The operator should not become alarmed when either of these things happen.

If you were suddenly confronted with jamming, without previous experience, it would appear impossible to work through. However, it is not really that serious if the following procedure is carried out:

1. DF on the jamming.
2. Use available anti-jamming devices on the receiver when provided.
3. Try moving the gain control up and down.
4. Try changing the receiver local oscillator tuning.
5. Keep operating.
6. Report the type and bearing of jamming to CIC.

The first reason for obtaining a hearing on the jamming is to determine whether or not it could be antenna is turned to an unjammed bearing.

Try changing receiver local oscillator tuning. When you change the oscillator tuning, you lose some of the height of the desired echo. However, if the jammer is not exactly on your radar frequency, there is a chance that you will detune the jamming signal more than the echo signal. Considerable improvement can sometimes be obtained this way. Try "swinging" the oscillator tuning dial in both directions to see which direction makes the greatest improvement. Note the correct setting of the oscillator dial so that it can he returned to its normal position when no jam is present, otherwise your radar will not give optimum results.

Even if the jamming is extremely effective, keep operating: do not turn your radar off. Turning your radar off informs the enemy that his jamming is effective, and makes the radar completely worthless. The effectiveness of the jamming may change from

4-SC/SK-8

SC-SK RADAR

time to time, and if you are persistent enough some information may be obtainable.

Report the nature and bearing of the jamming to CIC. Recognizing the type may be difficult because non-synchronous patterns sometimes appear blurted beyond recognition. Inasmuch as knowledge of the jamming type* may possibly help identify the jammer in some cases, this information should be reported.

If the equipment is provided with an anti-jamming receiver, the jamming may he reduced sufficiently for reading targets without any detuning of the receiver. Detuning should be a last resort, and then should be done very carefully and cautiously,

Maximum reliable range.

SC-2 RADAR

Antenna 90 feet

BB, CV, CB, Large auxiliaries	37,800 yards
CA, CL, Medium auxiliaries	25,000 yards
DD, DE, DM, AV, PC, CG	17,000 yards
Submarines	5,900 yards
Large planes, PBM, PB2Y	132,000 yards
Small planes, 6F6, TBF, SB2C	72,500 yards
Land	142 miles

otherwise all targets may be lost and the equipment made completely ineffective. No set procedure is offered for setting the controls of the AJ receiver, except that they should be varied for maximum readability through jamming, the gain control coming first and then the AVC control followed by Rej 1 and Rej 2. Turn all AJ controls to the OFF or NORMAL position when no jamming is being encountered.

Above all, never turn off the radar.

Even when jamming and/or deception is encountered, full 360 degree search must be continued. However, the antenna should be stopped for short intervals from time to time in order to try reading through the jamming (using the "A" scope). You also must be prepared for diversionary tactics, for the enemy may or may not use jamming and or deception to divert your attention from the bearing of the main attacking forces. This problem is simplified when similar but separate radars are used for reading through jamming and for searching.

PERFORMANCE

Ranges obtained on planes will vary greatly with the altitude of the plane, because of fade areas and the curvature of the earth. Large, high-flying planes have been observed at 120 miles. Average ranges on medium altitude planes are from 60 to 70 miles, and on low-flying planes from 20 to 40 miles on the SC-1, with better results on SC-2 and SK.

Ranges on surface targets will vary with antenna height, size of target, and weather conditions. In most cases, the ranges will be 6,000 to 10,000 yards shorter than those obtained on the same targets with surface-search gear.

SK RADAR

Antenna 130 feet

BB, CV, CB, Large auxiliaries	51,500 yards
CA, CL, Medium auxiliaries	35,000 yards
DD, DE, DM, AV, PC	226,500 yards
Large planes	250,000 yards
Small planes	150,000 yards
Land	170 miles

Minimum range.

SC-1, SC-2, SK "A" scope	1,500 yards
PPI	
20-mile range	2 1/2 miles
75-mile range	6 miles

Accuracy.

Reading directly from the PPI, range accuracy is 2,000 yards or better, and bearing accuracy 4 degrees.

Bearing and range accuracies for the different ranges on the "A" scope and PPI, when the antenna is sweeping or stopped, are listed in the table below.

Ranges	Sweeping		Stopped	
	Range	Bearing	Range	Bearing
30,000 yards	1,000	3 degrees	200	5 degrees
20 miles	1/2 mile	3 degrees		5 degrees
75 miles	1 mile	3 degrees	1 1/2 mile	5 degrees
200 miles	2 miles	3 degrees		5 degrees
375 miles	5 miles	3 degrees	1 mile	5 degrees

Resolution.

* See Part 3, Defense Against Jamming and Deception.

Bearing 10 degrees

Range 500 yards

4-SC-SK/9

RADAR OPERATOR'S MANUAL

TROUBLES

There are in general, two methods of improper operation. One will result in complete disappearance of all target indications from the screen. This should be observed by the operator instantly, and measures should be taken promptly to remedy the trouble. The other is a general decrease in the ranges obtained. Detection of this type of failure requires much greater alertness on the part of the operator.

The jar of gunfire or surge currents may cause the overload relay in the transmitter to kick out, cutting off the transmitter. The red transmitter pilot light will go out, all targets and the transmitter pulse will disappear from the screen, and the sweeps on the range and PPI scopes will be jittery, because they are not receiving a synchronizing pulse from the transmitter. The operator should turn down the high voltage variac, press the overload relay reset button, and then turn the high voltage variac back to its normal operating position. Should the relay continue to kick out, notify the maintenance man as to what occurred and what has been done.

A gradual decrease in the operating efficiency of a set is harder to detect. The operator must be on the lookout for this at all times. One indication may be the point to which the receiver gain control must be turned to get the normal amount of grass. The best indication is the ranges that are being obtained on objects with which the operator is familiar, such as ships in his group or land in the vicinity. If poor results are being obtained, the operator may try retuning the receiver. If this does not help, the maintenance man should be notified.

The operator can greatly assist the maintenance man by giving a true and accurate description of what happened on the scope when the set went our of operation. This is even more true of intermittent troubles.

4-SC/SK-10

PART 4

MARK 3 AND MARK 4 RADAR
(FC, FD)

MARK 3 AND MARK 4 RADAR
(FC, FD)

CONTROLS

Main unit.

1. *Plate current meter of modulation generator*: should read about 200.

2. *Plate voltage meter of modulation generator*: should read about 500.

3. *Load voltage*: should be set to 120 *at all times* by means of control No. 11. (A recent directive says 115, but do not set it at 115 unless the set has been adjusted for this.)

4. *Magnetron plate current meter*: should he set, to read about 30 by controls 13 and 12.

5. *Magnetron plate voltage meter*: should be set to 12 (12,000 v.) by means of control No. 12.

6. *Magnetron filament voltage meter*: should read 13.5. Can be seen by looking through the wire mesh on the front of the transmitter.

7. *Frequency control of modulation generator*: adjusted by technician.

8. *Radio dial light dimmer*: controls the brightness of the illuminated dial on the receiver.

9. *Receiver tuning control*.

10. *Receiver sensitivity control*:

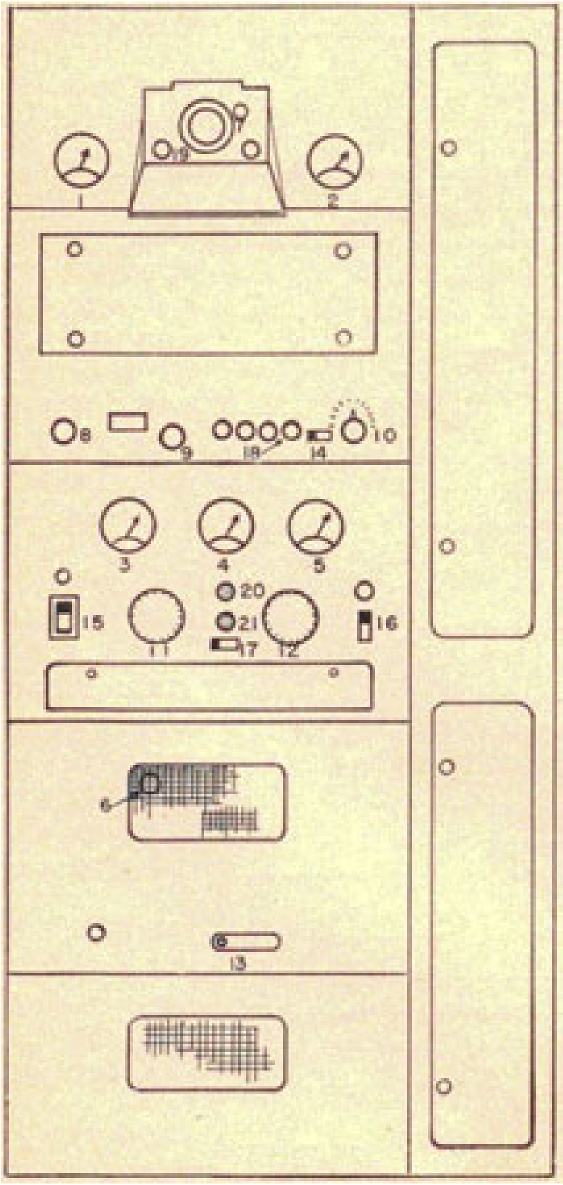

Figure 4 Mk. 3/Mk. 4-1. Main unit.

11. *Load voltage control*.

12. *Magnetron plate voltage control*.

13. *Field control*: adjusts plate current to the magnetron.

14. *Remote-local switch*: determines whether the receiver sensitivity is controlled from the main unit by control No. 10, or whether the sensitivity is controlled by the receiver sensitivity knob on the range scope.

15. *Main off-on switch or line switch*.

16. *Plate off-on switch*.

17. *Dim-bright switch*: controls brightness of the pilot lights on the face of the main unit.

18. *Mon jack*: used in tuning up the receiver.

19. *Audio jack*: used to obtain a synchronizing voltage when tuning up the receiver.

20. *Screw lock for 21*.

21. Magnetron filament voltage adjustment.

Control and indicator unit (range scope).

1. *Intensity control*: controls the brightness of the picture on the scope.

2. *Image spread control*: controls the size of the notch and expanded sweep.

3. *Receiver sensitivity control*: controls height of the grass and echoes.

4. *Focus control*: focuses the image on the face of the scope.

5. *Sweep gain control*: controls the length of the sweep. Should be completely clockwise.

4-Mk. 3/Mt. 4-2

MARK 3 AND MARK 4 RADAR

6. *Lobing on-off switch*: turns lobing motor on or off.

7. *Transmitter standby switch*: turns the transmitter on or off. Used as a stand-by switch.

8. *Pilot light dim-bright switch*: (to be replaced by an A.G.C, switch.) Some sets have an anti-jamming switch above control 2.

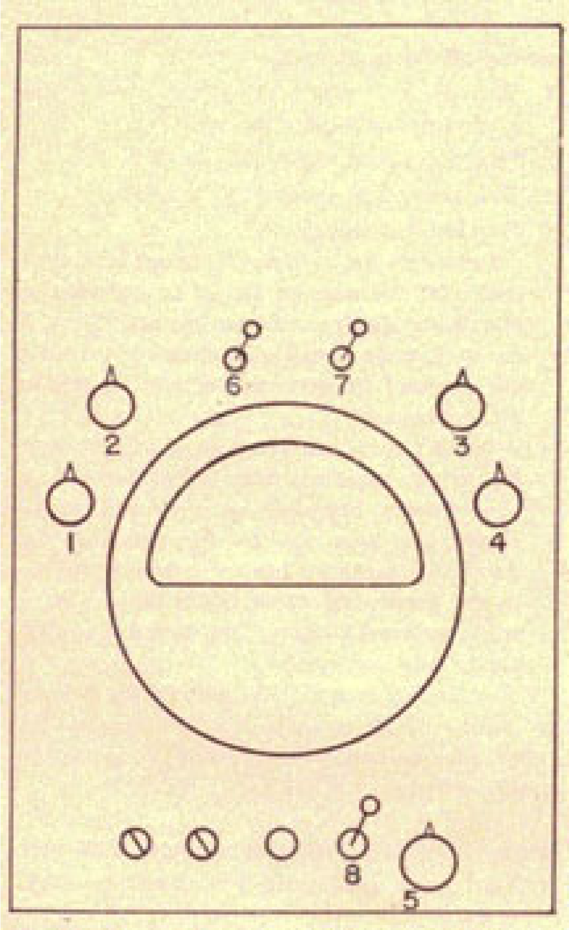

Figure 4 Mk. 3/Mk. 4-2. Control and indicator unit.

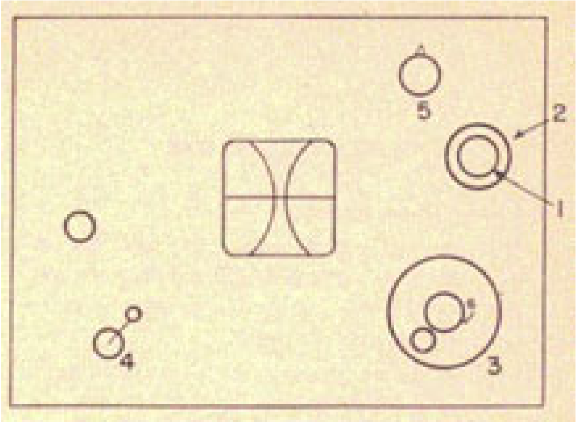

Figure 4 Mk. 3/Mk. 4-3. Range unit.

Train or elevation indicator.

1. *Intensity control*: controls the brightness of the image.

2. *Image spacer control*: move one sweep with relation to the other.

3. *Sweep expansion control*: opens or contracts the two steps.

Range unit.

1. *Inner knurled nut*: locks friction drive between the range knob, No. 3, and the electrical system controlling position of pips on the lace of the scope.

2. *Outer knurled nut*: moves images across the scope.

3. *Range knob*: moves images across the scope.

4. *Pilot light bright-dim switch*.

5. *Dial light bright-dim control*.

6. *Signal button*.

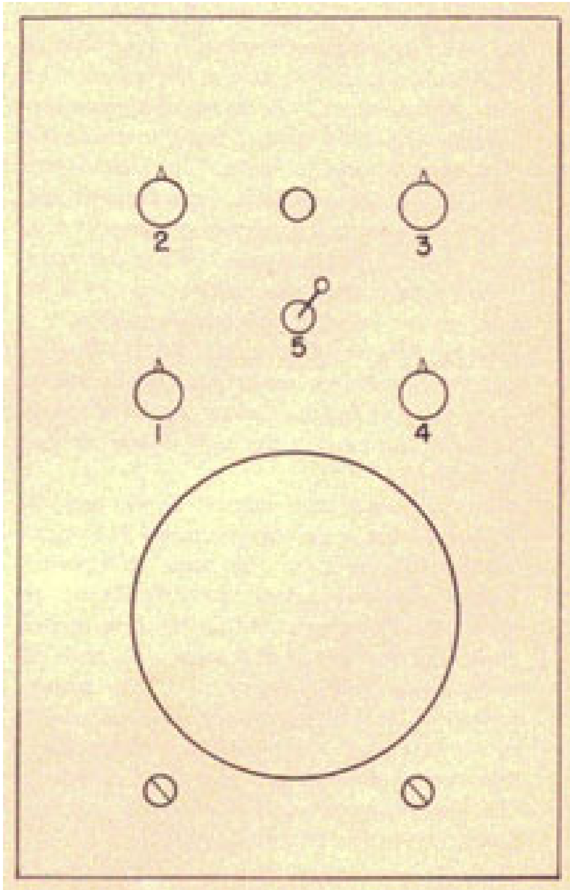

Figure 4 Mk. 3/Mk. 4-4. Train or elevation indicator.

4. *Focus control*: focuses the image.

5. *Pilot bright-dim switch*.

TURNING ON AND OFF

Turning on the main unit.

1. Make sure main off-on switch (15) and plate off-on switch (16) are turned OFF and the plate voltage control (12) is turned *completely counterclockwise (against the stop)*.

2. Turn on line transformer switch (mounted somewhere on the bulkhead).

3. Check magnetic controller switches (if any).

If not, adjust to this value by magnetron filament voltage adjustment (21).

10. Check to see if the remote-local switch (14) is on REMOTE. The main unit is now turned on and the set is all ready to operate. It is a good policy to tune up the receiver upon turning on the set, and about once every hour thereafter-more frequently if the set is subjected to serious vibration or temperature change.

Turning off the main unit.

1. Turn the plate voltage control (12) counterclockwise slowly until it hits the stop.

2. Turn plate on-off switch (16) to OFF.

4. Turn on stand-by rotary switch near C and I Unit (when installed).

5. Turn on transmitter stand-by switch (7) on C and I Unit.

6. Turn on the main off-on switch (15). Before turning on anything else, listen to see if the blower fan cooling the magnetron starts running as soon as the main switch is thrown. The load voltage meter (3) should go to 120 volts. Adjust it to this value by means of the toad voltage control (it) and make sure it stays at this value. The plate voltage meter (2) in the modulation generator will swing to the right of the scale and slowly come down to about 500 volts. The plate current meter (1) on the modulation generator will start at zero and after a few seconds will slowly come up to about 200 milliamperes. When this meter reaches a stable value, the 1,639 c/s note will be heard coming from the modulation generator.

7. Turn on the plate off-on switch (16). *Wait at least 5 minutes* before turning up the plate voltage. When the plate switch is turned on, the two tubes located in the front of the high voltage rectifier light up.

8. After 5 minutes have elapsed, slowly turn up (clockwise) the plate voltage control (12) until the plate voltage meter (5) reads 12 kilovolts. Make sure the plate current meter (4) does not go above 30 milliamperes. Adjust the held control (13) until the plate current meter (4) reads 30 milliamperes (30 milliamperes is an average value, it will he different on some sets). The plate current and plate voltage are not independent. Any change affecting one will affect the other. Thus both plate voltage control (12) and held control (13) must be moved together.

9. Check filament voltage meter (6) to see if 13.5

3. Turn main off-on switch (15) to OFF.

4. Turn bulkhead switches off.

> Every time the main unit is turned on from a cold start, the wear on the set is equivalent to three hours steady running of the set. Thus, if the set is to be turned off and on eight times a day it would be more profitable to let the set run continuously.
>
> Another even more important consideration in this respect is that it requires approximately three hours running before the set is warmed up sufficiently for most accurate operation. If the modulation generator has a red light at the top of the front panel which flashes off and on, it will take a much shorter time to warm up (approximately one hour).

When turning on any of the units in the director, the stand-by bulkhead switch, which turns on the scopes, must be turned ON-reverse procedure, for securing the gear.

Turning on the control and indicator (C&I) unit.

1. Turn sweep gain control (5) completely clockwise.

2. Turn intensity control (1) clockwise until an indication is observed on the face of the scope.

3. Focus the trace by means of the focus control (4). *Note*: For each setting of the intensity control there is a distinct setting of the focus control. Be careful not to make the trace too bright. The trace should never be so bright that the return trace can be seen over the notch. (This undesirable condition is apparent when the notch is fully expanded. It makes the notch look like a box.)

volts are applied to the filament of the magnetron.

4. Turn the image spread control (2) completely counterclockwise.

4-Mk. 3/Mk. 4-4

MARK 3 AND MARK 4 RADAR

5. Turn the receiver sensitivity control (3) clockwise until the grass is about a half-inch high.

6. Make your "zero set" and continue to check it as frequently as possible while operating the set.

7. Turn the transmitter switch (7) on. The instant this switch is turned on the set is "on the air." The main frame should never be turned off and the transmitter should be controlled by means of this switch; the switch is designed to do this, If it is found that fuses are blown by doing this, it is an indication that some element is not functioning properly and should be promptly remedied.

8. The lobing motor should he turned on only when using the set. It should remain on while searching for targets and while tracking. But remember, whenever the set is not actually being used, turn the lobing motor off.

Turning off the control and indicator unit.

1. Turn off lobing motor (6).

2. Turn off transmitter (7).

3. Turn intensity control completely counterclockwise (1).

Turning on the trainer's and pointer's scopes.

1. Turn the image spacer control (2) completely clockwise.

2. Turn the sweep expansion control (3)

connected to the grounded side which on RCA scopes is marked with a zero. The RED, or high side is connected to the top of the two vertical terminals which are marked high. Plug this cord into the right hand plug of the four jacks in the radar receiver panel; this is marked mon (18).

2. Connect another patch cord to the sync terminals. Connect the BLACK to the ground terminal and the RED to the high terminal. Sometimes the red and black markers have become obliterated. They can be readily distinguished, since the BLACK side, or ground side, is the outer conductor of the cable and probably will have no insulation on it. The RED side, or high side, is the inner conductor and will be insulated. This cable is plugged into the audio jack (19) in the modulation generator panel.

3. Turn the vertical and horizontal centering controls on the test scope to mid-position. Turn vertical amplifier knob off. Turn the horizontal amplifier knob to EXT. Turn the vertical and horizontal gain controls to zero. Turn the range to 550-4,500 (for RCA 155 A or B) or 700-7,000 (for RCA 155 C). Turn the frequency to zero. Turn the sync knob to zero.

4. Plug in the scope to 110 volts AC and turn the intensity clockwise until a click is heard.

5. Wait for about one minute and then turn the intensity control clockwise until a spot is observed on the screen. *Be careful that this spot does not become bright.* Turn the horizontal gain control clockwise until a horizontal line covers the scope with a small margin left over at each side. Focus this line by means of the focus control. Adjust the

completely clockwise.

3. Make sure the range scope operator has the lobing motor turned on.

4. Turn the intensity control (1) clockwise until two horizontal lines appear on the scope. These lines will not be straight, but will be slightly curved.

5. Focus the traces by means of the focus control (4). It is important that the sweep should be just bright enough to see and no brighter. It should be focused to a fine, sharp line.

6. The image spacer (2) and the sweep expansion controls (3) should now be turned counterclockwise until the sweeps are about 1/4 inch wide and separated by about 1/8 inch.

Turning off the trainer's and pointer's scopes.

1. Turn the intensity control (1) completely counterclockwise.

Tuning the receiver.

1. Connect a patch cord to the vertical input terminals of the test scope. The BLACK side is horizontal and vertical centering controls until one line is centered on the face of the scope.

6. Turn the vertical amplifier to the ON position. Increase the vertical gain control until the pattern occupies about 10 divisions on the scope.

7. Turn the frequency control clockwise slowly. It will be noticed that images will be formed on the face of the scope with the pips displaced downward from the horizontal sweep. As the control is advanced, first, four pips will be formed, then three, then two, and finally one. When one image is formed, it will be found that it will be almost impossible to make that pip appear stationary on the scope. Get it as steady as possible, then slightly turn the sync control clockwise, and it will be found that the image on the scope will

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lock in and cease to move, The image thus formed will be the same picture that is on the C and I scope in the director, except there will be no notch and there will be no expanded portion of the sweep. It should be noted here, that the operator might find the actual tuning procedure, which is about to be described, easier if he stops the image on the screen with two pips on it rather than one. This is largely a matter of preference, By adjusting the horizontal gain and the horizontal centering knobs, the operator can make the two pips line up with the divisions on the graduated face of the scope. By counting the number of divisions between the pips, and realizing that this distance corresponds to 100,000 yards, it is possible for him to estimate roughly the distance to any target.

8. Turn the remote-local switch (14) to LOCAL, and the height of the grass and the echoes may be controlled by the receiver sensitivity control (10), located on the front panel of the receiver. Turn the receiver turning control (9) back and forth until the pips come to a maximum, and decrease on each side of the maximum point. By going back and forth over this point several times, it is possible to find accurately the position of the knob which gives maximum echoes on the test scope. It is best to tune on small echoes and get them as big as possible.

Note. For precise tuning, it is absolutely necessary that no one move the antenna while the receiver is being tuned, either in train or elevation. It is also highly desirable that the echo used to tune the set be a steady pip from a land target. This is the only tuning adjustment the operator need know. Further tuning requires the more extensive knowledge of the maintenance man.

CALIBRATION

3. Loosen the inner knurled nut (1) located above the range crank,

4. Turn the outer knurled nut (2), and move the image across the scope until the left-hand edge of the transmitted pulse coincides with the left-hand edge of the notch. Adjust this nut until the left-hand edge of the notch falls half-way down to the bottom of the notch.

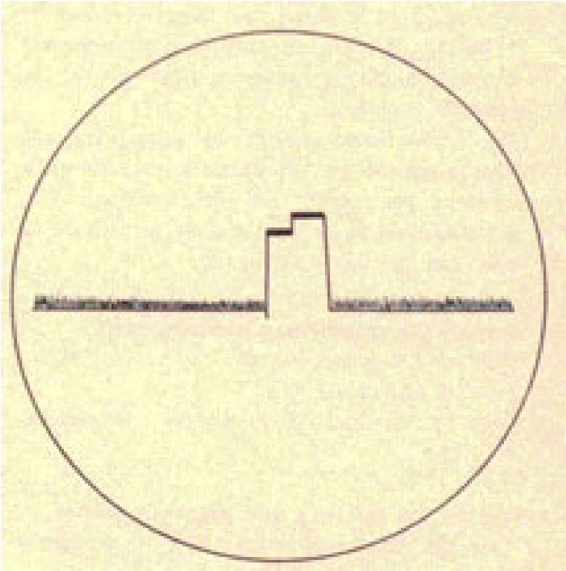

Figure 4 Mk. 3/Mk. 4-5. Transmitter pulse position for correct zero set.

5. Check to see if the range dial is at the zero set. and then carefully tighten the smaller knurled nut with the right hand, while holding the larger nut with the left hand to prevent it from turning.

6. Crank the pulse out of the notch, *then crank it back* to the position described in step 4 above, and check to see if the zero set has slipped while tightening up the smaller nut. If it has slipped, repeat the above procedure until the correct setting is obtained.

Note: The above procedure should be practiced until an accurate zero set can be made very rapidly. During the first half-hour after the radar has been turned on from completely off, the zero setting should he checked at least as frequently as once

Range zero set.

1. To show accurate ranges, it is necessary that the range dial be accurately calibrated so that zero range on the range dial corresponds to zero range on the scope. Turn the grass to the height usually used in operation (about half an inch), and turn the image spacer knob (2) completely clockwise.

2. Turn the range dial to the zero set given by the technician. It is a minus value of range, usually about minus 200 yards, at which the range dial is set, (A value of minus 200 yards is the same as a range of 99,800.)

every two minutes if accurate ranges are necessary during this time. After this time has elapsed, the zero setting may be checked less frequently. After three hours, the zero setting may be checked about once every half-hour, and always before each firing run in gunnery practice or battle, if practicable.

4-Mk. 3/Mk. 4-6

MARK 3 AND MARK 4 RADAR

Double range echo method of obtaining zero set.

(See Part 1. General Radar Principles.)

1. Train on another ship-the larger the better, on a course parallel to your ship and not more than 2,000 yards from it. (Between large ships, greater distances may be used.)

2. Start getting ranges on the other ship. It is important that the pointer and trainer remain right on the target during the following procedure.

3. If the other ship is close enough, two pips will be observed on the range scope. The closest pip will be saturated and the second pip will probably be quite small. The second pip will be at approximately twice the range of the first pip. (See fig. 4 Mk. 3/Mk. 4-6.)

distance between the first and second echoes, namely 1,500 yards.

5. The first pip is then placed in the notch and the range dial is set to the difference between the ranges of the first and second pips (in this case 1,500 yards), by means of the zero adjustment nuts.

6. After securing the zero adjustment nuts, the transmitted pulse is cranked back to the notch and placed as though making a zero set. The minus zero set is noted when the transmitted pulse is as shown in figure 4 Mk. 3/Mk. 4-5.

This zero set should be written down in a conspicuous place near the range unit, as it is the zero set that should be used. Steps 4, 5 and 6 should be executed as quickly as possible and repeated several times until consistent results are obtained. Occasionally, there will be two pips where the double echo should appear, and the range operator may not know which is the true double echo. One of these pips, however, will be clear and the other foggy. The clear one will be the double echo. The reason for this is, that if you are on the target the pip

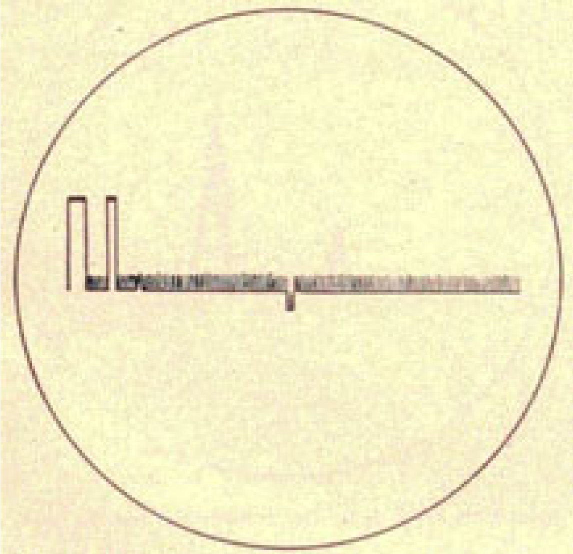

Figure 4 Mk. 3/Mk. 4-6. Double range echo.

4. The first pip is placed in the notch, and its range is noted. Let us say its range is 1,700 yards. Then the second small pip is placed in the notch, and its range is noted. Let us suppose its range is 3,200 yards. The difference between these two readings gives the accurate range between the two pips. In this case the range would be 1,500 yards. The range to the double echo should be just twice the range to the first echo, since the pulse has had to travel just twice the distance in forming the double echo that it traveled to the first echo. Therefore, the total distance traveled by the pulse in forming the double echo was 3,000 yards, and the distance to the first echo must be half that distance, or equal to the from the target will be clear and not foggy. A foggy target would indicate another ship, sore debris, or another extraneous target which is off the line of sight. Finding the zero set should be done only after the set has been on *at least three hours*, and is thoroughly warmed up. This is only one method of obtaining your zero set. Other methods are described in BuOrd Pamphlet No. 657.

***Train and elevation calibration.**

1. Alignments of the radar antenna with the optics is an easy matter. The trainer and pointer have merely to look through their telescopes when their pips are matched, to see if their cross-hairs cut the target. During an exercise using full radar control, the control officer can determine if the radar is aligned with the optics, by looking through his telescope when the crew gives the word that they are on the target.

2. Level and cross level should always he cut in when aligning the antenna.

3. To align the antenna in train, two men are placed on top of the director with wrenches to loosen the securing bolts, and move the adjusting screws holding the antenna. The trainer and painter

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* Note: This is a technician or Navy Yard job.

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stay on a small, distant target with their optics. The maintenance man watches the pips on the trainer's scope, and directs the men adjusting the antenna to move it to the right or left, as indicated by the pips on the trainer's scope. When the pips are even, the antenna is locked in place.

4. The antenna should never be checked for elevation accuracy at angles less than 15 degrees. If it is found to be off, it is realigned by training optically on a plane flying directly to the ship, and passing over the ship. The maintenance man should adjust the microcoupler on the antenna shaft, while watching the pointer's scope, until the pips on the pointer's scope are equal.

5. For more details see BuOrd Pamphlet No, 657.

OPERATIONAL TECHNIQUE

The range operator.

The range operator is the keyman of the FD team. Upon his shoulders rests the responsibility of supplying pips of the proper size to the trainer and pointer. It is up to him to select the particular target the gunnery officer may designate. He must also be able to tell what type of target a certain pip indicates, if a ship, the approximate size; if a plane, its size; if a number of planes, the approximate number in the flight. He must be able to distinguish the pip presented by a submarine from the water return which tends to confuse it. He must be ever alert to detect even the weakest echoes, and he prepared to get his team on them before they disappear.

The two greatest responsibilities of the range operator are: (1) to keep the pip in the notch, and (2) never to let it saturate (flatten on top due to too much receiver sensitivity). The pip must be kept in the center of the notch so that the pip appears even on the pointer's and trainer's scopes. If the range operator will find that after once setting up the scope correctly, there are only two knobs that require further adjusting. but those two knobs will have to be adjusted frequently. These are the image spread (2) control, and the receiver sensitivity (3) control. The receiver sensitivity must be readjusted as often as necessary, to prevent saturation of the pips seen on the pointer's and trainer's scopes. He should make all adjustments on the range scope with his left hand (or with his right if his left hand is on the range knob). He must know the position of all controls so well that he can make adjustments to the scope without groping for the knob or taking his eyes from the scope.

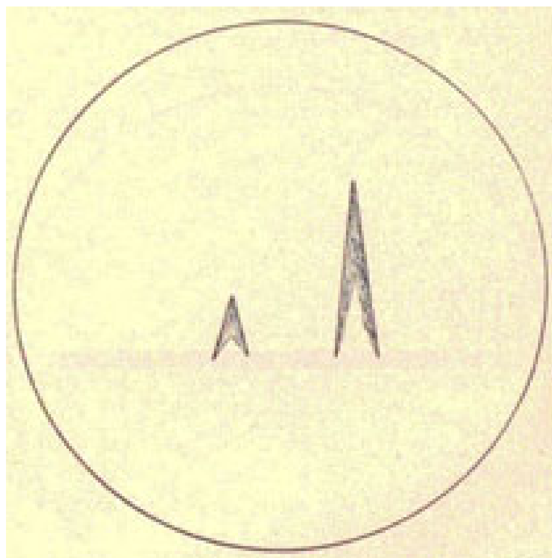

Figure 4 Mt. 3/Mk. 4-7. Pips on trainer's or pointer's scope.

The trainer and the pointer.

The trainer trains toward the smaller of the two pips. (fig. 4 Mk. 3/Mk. 4-7, train left.)

The pointer elevates if his left pip is lower. (fig. 4 Mk. 3/Mk. 4-7, elevate.)

A rule to follow is the *Three L Rule*. For the trainer: left, low, left; meaning if his *left* pip is *low*, train to the *left*. For the pointer: left, low, lift; meaning if his *left* pip is *low*, *lift* or elevate the antenna.

pip saturates on the range scope, it will saturate on the trainer's and pointer's scopes, thus preventing them from knowing which way to train or elevate.

One of the range operator's hands should always he on the range knob. When he wants to change range quickly, he should turn the range wheel with the small crank on it. For fine adjustment of range, such as keeping the pip in the notch, the operator should grasp the wheel with his hand and not use the crank. Usually this will be the right hand, but in some installations it may require the left.

The opposite hand (usually the left), should always be resting on the top of the range scope. The

Some pointers think of the left pip on their scope as an indication of the position angle of the antenna. If the left pip is low (in relation to the right pip, of Course), the antenna is pointed *below the target*. If the left pip is *high*, the antenna is pointed *above the target*. This is a good way to tell the position angle of the antenna.

When the pips are of the same height, the pointer and the trainer say. mark," or "on train," or "on point." Occasionally you will notice that the pips will act in reverse, in other words, when you train or point toward the lower pip, it will get lower rather than higher. This indicates that you have a minor lobe contact. The target actually bears 15 degrees to 20 degrees to the left or right of this.

Sometimes the trainer will be able to match up two pips, but no pips will show on the pointer's scope. This can be caused by minor lobes again, and the trainer should train back and forth until the pointer and the trainer both can see two pips. The angle between the minor lobes and the main lobe is 15 degrees to 20 degrees.

Below 12 degrees of elevation, the ED cannot be relied upon to give accurate position angles. With surface targets we know what the position angle is, and so are not concerned about the inability of the ED to give an accurate position angle. In train there is not this inaccuracy.

in the notch. To help speed op the process of getting the pip in the notch, the operator should have previously cranked onto his range dial the range given by the search gear. If the target should disappear, close the notch, hold the train and elevation and turn the range knob back and forth. Soon the pip will show up again, and this time the operator will be able to get it into the notch; the pointer and the trainer will also get a fix or an indication of which way to train or elevate before it disappears. This process should be continued patiently. If the pip is clear the range operator knows that the pointer and or trainer are on target. If the pip is cloudy, the trainer and pointer are off the target. On some targets, however, such as a flight of planes, it will be impossible to get a clear pip.

Searching when no bearings or ranges are given by the search-radar.

In searching, when bearing and range are not given by the search radar, practically the same method is used as was described in the preceding section. The

Searching with bearings and ranges given.

The approximate bearing and range will be given to the operator by CIC. The approximate range is placed on the range dial. When the director is trained to the approximate bearing, the lobing motor should be turned on, and a search begun through a small angle (15 degrees) for the target. The elevation angle should be varied from zero to about 10 degrees. It is most important that the image spread knob (2) be turned completely counterclockwise. The range operator must be extremely alert to see any echo that may appear along the length of the sweep. He should never allow his gaze to concentrate on one portion of the sweep for too long a time. Echoes frequently appear as a small, straight line, no higher than the grass, and the operator must be quick to notice them. Turning the range knob back and forth slightly helps somewhat, because echoes which ordinarily would be hard to distinguish from the grass become more readily discernible, appearing as small, bright lines, moving back and forth in the grass. The selector switch *should not* be on RADAR RANGE when doing this.

As soon as the range operator sees the target he should call out "mark," or "hold train and point," so that the pointer and trainer will stop searching. Then, opening the notch with one hand, and turning the range knob with the other, he should rapidly bring the target into the notch at no time losing sight of the target. If the target is at a great range, it will probably disappear by the time the operator has it only difference is in the range operator's use of the sweep gain control. While searching, when you do not know that there are any targets, the sweep gain control should be turned counterclockwise until the trace occupies only about three inches. Targets can still be seen with ease, and this method possesses the advantage that the operator will be able to keep the whole sweep under his eyes at once. An experienced operator will not have to do this as often as an inexperienced operator, since the experienced man can watch alertly the greater trace as easily as the inexperienced man can watch the shorter sweep.

It seems to be the current practice, to keep the lobing motor turned off at all times, except when actually tracking a target. The only valid reason for this is that it saves the lobing motor from excessive wear. This admittedly is important since the lobing motor and cam assemblies are one of the weakest units of the Mark 3 and Mark 4 radars. They are located in a place where it is difficult to work and repairing them properly is a tedious job.

There are many in the held, however, who feel, that the benefits to be derived from operation of the lobing motor for searching outweigh the disadvantages. The greatest benefit of using lobing while searching is that it causes the beam width to increase from 9 degrees, the normal width of the beam, to 15 degrees, the width of the radiation pattern between half-power points with the lobing on. This increased coverage accompanied by no loss in power, since actually

we are simply waving the same beam back and forth in front of the director. It is easier to spot a target quickly with the increased beam width than it would be if you had only the one 9 degree beam.

Another reason for keeping the lobing motor on while searching, is that, once a target is picked up, and the trainer and pointer get on it by using optics, the C and I operator will have no need to turn the lobing motor on. He probably could read ranges under this condition, but let us suppose the target was suddenly obscured from view for some reason, as the laying of a smoke screen, or the sudden appearance of a rain squall. The trainer and pointer would immediately turn to their radar to track the target, and it might take some time to determine that their lobing motor was not on, and another period of time to line up their scopes. In the excitement of battle, working under nervous tension, such a delay might easily be prolonged. Any delay, however slight, at such a time, might very well change the outcome of a battle. So if such a delay can be eliminated, even at the expense of giving the maintenance men additional work, it should be done, and the lobing motor should he left on.

When the lobing motor is turned off, the beam, which was being swung in four distinct positions, gradually comes to a stop. It might be pointed up into the air or down into the sea. It might be pointed to the right or left. There is absolutely no accurate method of telling just where the beam is pointing. In any case, it never comes to rest pointing along the line of sight. Thus you might be searching for a ship with the beam pointing up into the air. However, if you turn your lobing motor on when searching your beam will be swung in all four positions, and you can always be sure you will not miss your target because you know your beam is pointed in the right direction.

the target, thus not transmitting ranges continuously. Accordingly, a set-up on the director can be made more quickly by using radar ranges and rate control on the director than by any other means.

After the range operator has picked up the target and told the pointer and trainer to "hold train and point," he cranks the pip into the notch as described above. When it is in the notch, he says loudly, "on target." This indicates to the trainer and pointer that he has a pip in the notch and they accordingly look closely for it. When they have their pips matched up, they each say "mark." They continue saying "mark" whenever their pips are matched, and the range operator continues to say "on target," whenever he has the pip in the notch and the pointer and trainer are still using their radar.

Another good method is for the range operator to say "on range"; the trainer, "on train"; and the pointer, "on point."

The control officer will instruct the range operator as to the procedure and doctrine of pushing the range button. This range button is located in the center of the range knob and, when pushed, signals plot that the range is on at that instant. It also activates the range rate mechanism.

Spotting.

It is possible to see the shells leave the guns of your ship and follow them for quite a distance on the scope. Sometimes they look like "mice running under a carpet." Usually, they appear as distinct pips and move across the scope. You can also see shells from the enemy coming toward you on the screen. That should not prove too disconcerting, since they could miss your ship by quite a distance and still appear to be coming toward it,

The range operator has the additional function of spotting misses. This is done by estimating the

Tracking.

Gradually the pip will become strong enough that it may he continuously tracked. When this occurs, the computor may be switched in, if full radar control is desired. As soon as the target is close enough to appear in the pointers and trainer's telescopes, the optical rangefinder should notify the control officer, and the trainer and pointer should switch over to their optics. Radar ranges should be used whenever possible, since they are more accurate than optical ranges. Furthermore, radar will give the range to the target continuously, whereas most stereo-rangefinders have to put their reticules back and forth over distance from the target's pip to the pip produced by the miss. The notch should be completely expanded. The width of the notch and the width of the expanded portion of the sweep should be determined for the operator's set. This can be accomplished by cranking an echo, or the leading edge of the transmitted pulse across the notch or sweep, and noting how much range was covered on the range dial. The notch is generally about 600 yards wide, and the expanded portion of the sweep about 6,000 yards. If the set is in perfect operating condition, the notch should remain in the center of the C and I scope. You can estimate the spot by mentally comparing the distance from the target to the splash with the

width of the notch. Some ships have installed a scotch tape scale on the face of the range scope to aid in spotting.

Determining composition.

Skill in identifying targets by means of their pips is largely developed by experience. Aircraft pips flutter up and down vigorously. Their bearing, range, and elevation change rapidly. Clouds and atmospheric conditions which sometimes give echoes similar to planes are easily distinguished by means of their slow change in bearing, range, and elevation. Sea-return, which also looks like planes, usually appears within 2,000 yards, and it is impossible to obtain a bearing on it. Two planes flying together produce a beating effect, and their pip will bounce up and down with some regularity. A group of planes will produce a large echo which is never clear inside. They can be picked up by a good operator at 90,000 yards if they are high enough, and the set is operating properly.

classified as unintentional interference rather than jamming.

If the range scope seems to be jammed, report the fact immediately to the control officer, and also to the maintenance man. *Continue to try to work through the jamming*. Turning your lobing off may help. Sometimes the narrower antenna beam resulting when lobing is off will enable the operator to direct the beam on the target alone, and not on the target plus the jammer, as might well happen with lobing on, and double the area being covered. Thus the operator might be able to range on the target, but he would have to turn the lobing on again to get a bearing. Vary your receiver sensitivity control (3) carefully to determine the optimum setting. Return the receiver sensitivity control to its normal setting when the jamming ceases, or when operating on unjammed bearings. This is important, because targets may sometimes be visible at low sensitivity control settings in the presence of jamming, but completely absent at the same sensitivity control setting when the jamming ceases.

The range to surface targets is limited by the horizon. Ships produce pips which will fluctuate up and down rather slowly; the larger the ship, the slower the fluctuation of the pip. They change range and bearing (but not elevation) slowly. Land targets are steady and strong. Sometimes land echoes will fluctuate like planes or ships. Good judgment together with experience will enable you to identify such pips as echoes from land. Satisfactory results cannot always be obtained when tracking a sleeve, for the sleeves in current use give echoes too weak to be used properly.

If the radar team must be coached on to the target by means of optics, they are knowingly passing up one of the greatest advantages we possess over the enemy. Radar should always pick up the target when it is far beyond optical ranges. Remember, that your skill as an operator will increase with practice. When you are able to distinguish an SBD from a TBF by the difference in their pips, you have really accomplished something.

Anti-jamming technique.

Oilier radars may produce interference on the range scope. This, as well as electrical faults in the set itself, can produce effects which might be called jamming by the inexperienced operator. If the interference is caused by the transmitted pulse from another radar set, an occasional pip will move across the screen in either direction. Effects which occur on all bearings or on the same relative bearing should also be

It is possible to train on the jamming station by simply matching the height of the jamming in the trainers pips. Remember, that the jamming will probably be much stronger than most echoes, and will tend to produce saturation signals. Therefore, when matching pips in jamming be sure that the gain control is turned down sufficiently, otherwise it will be difficult to pip match. Two ships can thus get a fix on the jammer. The pointer should also match the jamming on his scope. Remember though, minor lobes are much more important when being affected by a jamming signal than they normally are. So be very careful when using this method that you do not get on a minor lobe when matching up the height of the jamming on the two scopes.

Rotate the antenna to determine whether the jammer and the target are on the same bearing. *If they are not on the same bearing, a pointing and training error of several degrees or more is to be expected*, even if it is apparently possible to match pips. Report this to CIC. When the target and jammer are *less than 5 degrees apart* in bearing it will be difficult to determine whether the jammer is on or off the target bearing. The accuracy of range information is not seriously affected by jamming on any bearing, but it will, of course, be more difficult to obtain. It will be found that the pip matching scopes are more difficult to interpret than the range scope when jamming is encountered.

The maintenance man can change the frequency of

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the transmitter slightly by varying the field control, and the plate voltage of the magnetron, or by varying the duplexer tuning. This method is valuable, but the jammer may shift to your new frequency. Changing the receiver local oscillator tuning at the main frame may also be of some assistance.

As pointed out previously, it is of the greatest importance to keep trying to work through the jamming. The jammer will have to stop operating occasionally to check your frequency. in order to see if it has been changed. The second he stops jamming, obtain ranges and bearings (sometimes position angles), on the target. You must keep alert in order to get on the target almost instantly.

Some sets have an anti-jamming modification installed in the C and I unit. Turning this device on will sometimes improve the C and I scope. Always remember to cut all anti-jamming devices out of the circuit when no jamming is present.

The official policy is to keep your transmitter on at all times, attempting to work through the jammer, even though at first glance it may seem impossible to do so. Perseverance and patience will be rewarded many times by your being able to range on the target. Because the echoes increase more rapidly with decreasing range than the jamming signal increases, it may he possible to suddenly see the pip from a closing target. This is another reason for leaving the transmitter on at all times.

Never give up hope. Look for small discontinuities in the jamming, they might well be echoes. The British have shown that good jamming is extremely difficult to carry out successfully. So keep trying to work through the jamming, be patient, and above all do not get excited. A cool head is the best anti-jamming device ever discovered.

RELIABLE RANGES OF MARK 3 RADAR

	75' Antenna height		**125' Antenna height**	
Type	Without preamp.	With preamp.	Without preamp.	With preamp.
Large ships-(BB, CV, Large Aux.)	17,500	20,000	20,500	27,000
Medium ships-(CA, CL, Med. Aux.)	15,000	17,000	18,500	25,500
Small ships-(DD, DM, AD, PC, etc.)	11,500	13,000	13,500	18,000
Submarine (surfaced)	4,500	--	10,000	7,000
Submarine (periscope)	2,500	--	--	--
Large planes-(PBM, PBY, PB2Y, etc.)	25,500	20,500	23,000	36,500
Small planes-(SOC, OS2U, SBD, F4F, etc.)	14,000	8,000	15,000	--

RELIABLE RANGES OF MARK 4 RADAR

	75' Antenna height		**125' Antenna height**	
Type	Without preamp.	With preamp.	Without preamp.	With preamp.
Type	Without preamp.	With preamp.	Without preamp.	With preamp.
Large ships	16,000	18,500	15,500	26,000

Medium ships	12,000	15,500	16,000	25,000
Small ships	9,000	11,000	11,000	18,000
Submarine (surfaced)	3,500	--	7,000	--
Submarine (periscope)	--	--	4,000	--
Large planes	22,500	16,000	21,000	47,000
Small planes	13,500	13,500	13,000	23,500

4-Mk. 3/Mk. 4-12

MARK 3 AND MARK 4 RADAR

PERFORMANCE

Maximum reliable ranges.

The tables on the opposite page show the maximum reliable ranges of the Mark 3 and Mark 4 Radar. The figures given are the averages of many ships reporting. These data are taken from BuShips' publications.

A good crew with well-maintained sets should he aide to get considerably better results than these.

Minimum ranges.

On ship targets the minimum range is 800-1,000 yards. The minimum range on aircraft is 1,100-1,700 yards.

Accuracy characteristics.

The following table is taken from BuOrd Pamphlet No. 657, and shows the accuracy-resolution characteristics of the Mark 3 and Mark 4 Radar, using three different antennas.

Resolution.

The range resolution of the Mark 3 and the Mark 4 is 400 yards. The bearing resolution of the Mark 3 (3' x 12' antenna) is 5 degrees. The bearing not perpendicular to the shore line, the bearing resolution of the set comes into the problem, and it will be more difficult to pick up the target. The greater the deviation from the perpendicular, the farther out from the beach the target will have to be to be distinguished from the land by the radar. This can be seen in figure 4 Mk. 3/Mk. 4-8.

The same dependency on accurate knowledge of the range and bearing resolution also conies into effect when there are a number of ships steaming in column making a target angle of 90 degrees or 270 degrees. If the ships are close together they will appear as one pip on the range scope. If they made a target angle of 0 degrees or 180 degrees they would have to be separated by 400 yards to be seen as distinct pips.

Many similar applications of these principles will he obvious to the thoughtful operator. For example, suppose that a ship is stationed off the mouth of a harbor or large river waiting for the enemy to come out. Assume the target to be midway in the mouth of the passage. So long as the shores did not intercept the two lobes (as they would if the channel were narrow or the target close to one side), land at the same range as the target would appear on the range scope, and it would be difficult to range on the target itself. Let us also suppose that two planes are coming toward your ship, both at the same range and close together. If they are not too far apart (subtending an angle of less than 10 degrees) the

resolution of the Mark 4 is 10 degrees.

These are important figures, and they should be kept in mind at all times. If a target is greater than 400 yards offshore, a Mark 3 or Mark 4 will distinguish the target from the land as long as the line of sight to the target is perpendicular to the shore line. In this ease, only the range resolution of the set is being used. If, however, the line of sight is

radar, unable to distinguish each individual plane, would train at a point midway between them. The same would be true of two ships.

Characteristic	**FC long ant.** (3' X 12')	**FC Short ant.** (6' X 6')	**FC Antenna** (6' X 7')
Maximum range by direct indication (nominal range)	100,000 yds.	100,000 yds.	100,000 yds.
Minimum range (approx.)	1,000 yds.	1,000 yds.	1,000 yds.
Horizontal beam width (lobing off)	4.6 degrees	9.0 degrees	9.0 degrees
Vertical beam width (lobing off)	30.0 degrees	11.0 degrees	19.0 degrees
Horizontal beam width (lobing on)	7.2 degrees	15.0 degrees	15.0 degrees
Vertical beam width (lobing on)	30.0 degrees	11.0 degrees	15.0 degrees
Range accuracy	+/-40 yds.	+/-40 yds.	+/-40 yds.
Bearing accuracy	+/-2 mils	+/-4 mils	+/-4 mils
Elevation accuracy*	--	--	+/-4 mils
Range resolution	+/-400 yds.	+/-400 yds.	+/-400 yds.
Bearing resolution	+/-5 degrees	+/-10 degrees	+/-10 degrees
Elevation resolution*	--	--	+/-10 degrees

* Elevation data applies only when antenna is elevated above 10 degrees.

What has previously been said regarding the horizontal plane, also applies to the vertical plane. The elevation resolution is 10 degrees.

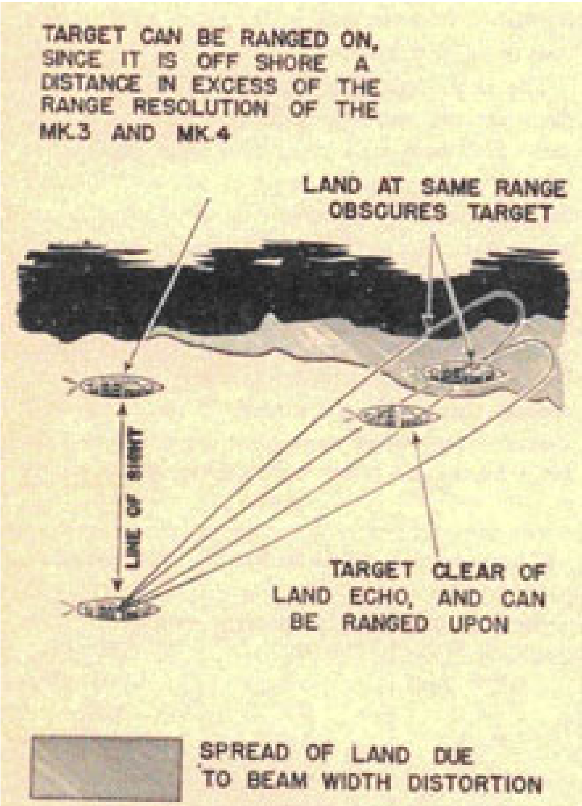

Figure 4 Mk. 3/Mk. 4-8.

TROUBLES

When the scope will not light up, or there is no transmitted pulse, it is obvious at once that something is wrong with the set. However, there are many minor malfunctions which only the experienced operator will notice. For example, when the image spread knob on the range scope is varied, that is, if tile position of the notch (not the width) moves across the face of the scope, and does not remain in the exact center of the sweep, the set is not functioning properly. (In this ease, the 29.5 KC and the 1.64 KC gears in the range unit may need realigning.)

Sometimes a false echo is seen at about 50,000 Yards on the range-scope. This can readily be detected as a "ghost," since it is present for all angles of train. (In this case, the fault may be caused by parasitic oscillations in the 807 tubes in the modulation generator. It can be removed by changing tubes or by soldering a small piece of wire to the cathode connection of one of the tube's sockets.) Double humps in the pips can be caused by faulty receiver tuning. Often the pips will saturate too soon on the trainers and pointer's scopes. In other words, the pip will only seem F-3 on the range scope, yet will be saturated on the other scopes. (This can be remedied by changing R88 in the C and I scope from 2K ohm to 1,200 ohms.)

All these are minor faults, yet for peak operating efficiency they must be eliminated. An operator should consider it an important part of his job to see to it that the set is kept in the best condition at all times.

4-Mk. 3/Mk. 4-14

PART 4

SA RADAR

TROUBLES 4-SA-10

4-SA-1

RADAR OPERATOR'S MANUAL

SA RADAR

CONTROLS

Like all other radars, the SA is a complex instrument, requiring careful and precise adjustment and operation. Many of the adjustments should be made by the operator, and the controls are conveniently placed so that this may be done.

The controls with which the operator must concern himself may be divided into five main classifications: power controls and indicators, selector switches, operating controls and indicators, adjustments, and alarms. The majority of these controls arc found on the receiver-indicator panels, which are located at the operating position. A few of these controls are mounted on the transmitter unit which is usually installed elsewhere in the ship. One control (on-off switch) is mounted on the train control amplifier cabinet.

The various controls and associated meters and dial lights are listed and explained below. Their arrangement is shown in the accompanying drawings.

Power controls.

P-1. *Main power switch* (labeled *main power emergency*): controls all power to the set except that to the heaters. Power is applied to the set when this switch is in the UP position.

P-2. *Line voltage meter*.

indicator circuits. When it opens, no trace appears on the screen and no dial lights come on.

P-9. *Emergency off* (on transmitter) : this switch opens the high voltage circuits in the transmitter.

P-10. *Plate current meter* (on transmitter): indicates the same thing as P-5 on control-indicator panel.

P-11 *Fil. primary voltage variac* (on transmitter) an adjustment of the filament voltage applied to the transmitter tubes.

P-3. *Line voltage variac*: controls the voltage applied to the set. It should be adjusted so that the line voltage meter (P-2) reads 115 volts continually.

P-4. *Transmitter power switch* (labeled *plate voltage*): applies the high-voltage to the plate voltage variac when in the UP position.

P-5. *Plate current meter*: indicates the DC current flowing through the transmitter tubes.

P-6. *Plate voltage variac*: controls the voltage applied to the transmitter tubes. (The numbers around this knob indicate only *relative voltages*, and *not* actual amounts.)

P-7. *Fuses* (labeled "5 amp. fuses") : these fuses are in the power line to the lobing and slewing motors. If either or both should blow, the antenna must be rotated by manual control or by the emergency train motor (control S-2). Lobe switching is impossible when fuses are open.

P-8. *Fuse* (beside dimmer control) : protects the

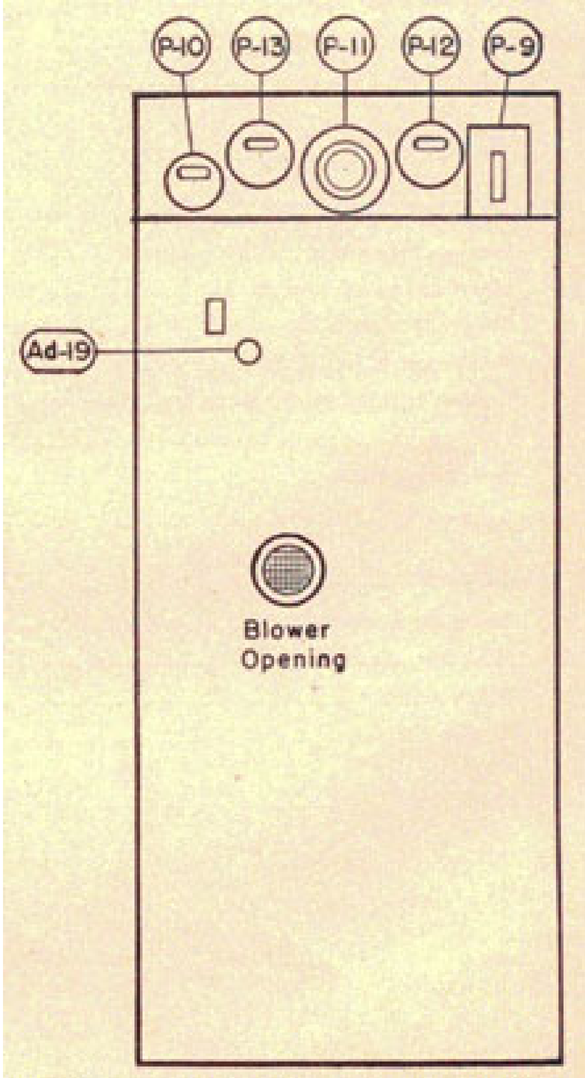

Figure 4 SA-1. Transmitter unit.

P-12. *Fil. voltage meter* (on transmitter): indicates voltage on the primary of the filament transformer that supplies voltage to the filaments of the oscillator tubes. Control P-11, should be adjusted until the meter reads the same voltage as that marked on the small card above it.

P-13. *Hours operation meter*: records the total time the filament voltage has been applied to the transmitter tubes.

Selection switches.

depend on the TCA for power. If the TCA should fail, this switch permits a continuation of the search.

S-3. *Slewing motor-low, off, high*: when switch S-2 is in auto position, this slewing motor switch permits automatic rotation of the antenna at either of two speeds (1 rpm or 4 rpm), or manual rotation of the antenna.

S-4. *Range sel* (range selector): setting of this switch determines the range scale being used: 30,000 yard scale when in position A, 75 miles when in position B, and 375 miles in position C.

S-1. *Antenna train-relative, true*: when in relative position, the antenna will stay on the same *relative* bearing when the ship changes heading. When in true position, the antenna stays on the same true bearing as the ship changes course.

S-2. *Emergency train*-CCW, auto. CW: the setting of this switch determines what unit will govern rotation of the antenna. When in auto position, the antenna may be rotated by hand, or controlled by the Mewing motor (control S-3). In either case, power passes through the train control amplifier (TCA). When the switch is in the CCW or CW position, the antenna is turned either counterclockwise or clockwise (respectively) by a motor which does not

S-5. *Cal-fid IFF*: the setting of this switch selects the picture seen on the screen. When in cal position (extreme CCW), range markers appear. When in the No. 2 position, the usual "A" scope picture appears, but maximum strength of the pips is limited so that the PPI scope (if any) will not be damaged by too much echo intensity. Position No. 3 is the same as position No. 2, except that maximum pip height is greater. Position No. 4 is used only when challenging a target for IFF response. It operates the interrogator (at present, the BL), and removes the range step.

S-6. *Cal synch (calibrate, synchronizing switch)*: this switch, with switch S-5 controls the picture on

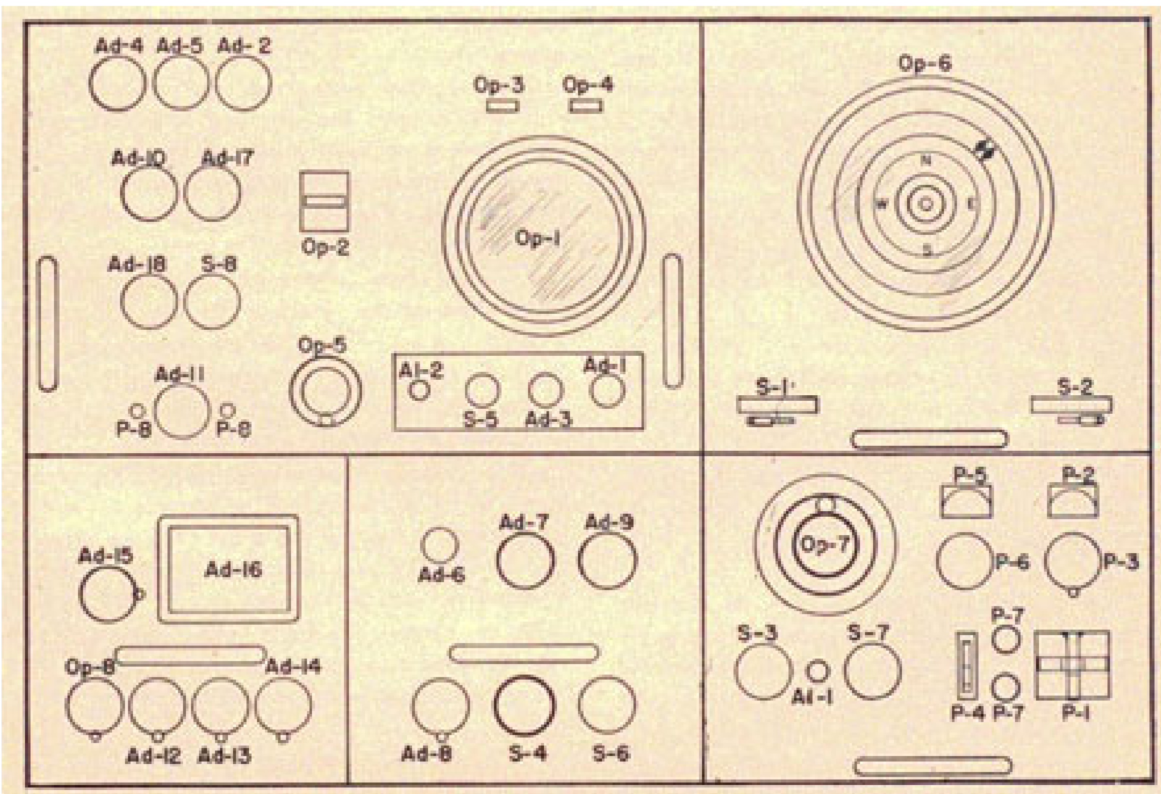

Figure 4 SA-2. Receiver indicator unit.

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the screen, and on the "osc. adj. scope" (2-inch CRT). When in position 1, any strong signal occurring at a rate of about 60 cycles per second will "synchronize the sweep" so that a strong pulse will appear fairly steady on the sweep. This is called internal synchronization. In position 2, the sweep on the scope is started by the transmitter pulse.

S-7. *L.R. motor-on, off, on*: this switch controls the lobing motor. The lobing motor is turned on by switching to either the left (CCW) or right (CW) position. The lobing motor (left-right motor) is off when the switch is in the OFF (center) position.

S-8. *L.R. off*: this switch makes normal search possible even while the lobing motor is on. When lobe switching (L.R. motor is on), two traces from each target normally appear on the screen. However, when searching, too pips would be confusing, so this switch is used to permit blanking of the right-hand trace when thrown to position 1. When in position 2, both pips appear.

Operating controls and indicators.

Op-1. *Range oscilloscope* (the scope) : the cathode-ray tube used to indicate presence of the echoes and to permit ranging on these echoes.

Op-2. *Yards range counter*: indicates the range in yards, corresponding to the step position on the scope when control S-4 (range selector switch) is in position "A" (or, in other words, when set for a 30,000-yard nominal range).

Op-3. *"B" miles range counter*: dials indicate the range, in nautical miles, corresponding to the step position on the scope, when control S-4 is in position B (for a 75-mile nominal range).

Op-4. *"C" miles range counter*: indicates the white bug used when lobe switching and matching pips.

Op-7. *Manual antenna-train knob*: this knob makes it possible to rotate the antenna manually to any bearing desired, so long as control S-2 is in the AUTO position. When control S-3 is in either the LOW or HIGH position, the antenna rotation may he stopped or reversed by operating this handle.

Adjustments.

Ad-1. *Focus*: controls the sharpness of the picture on the screen of the range scope (Op-1).

Ad-2. *Astig (Astigmatism control)*: no single setting of the focus control (Ad-1) can bring all parts of the sweep into correct focus. This control permits the operator to bring any desired part of the sweep into a sharper focus. The astigmatism control may he considered as a fine adjustment of the focusing.

Ad-3. *Intensity*: controls the brilliance (or intensity) of the trace on the screen of the range scope.

Ad-4. *Horiz (Horizontal centering control)*: the complete trace on the range scope (Op-1) may be moved horizontally by adjustment of this control.

Ad-5. *Vertical (Vertical centering control)*: the complete picture on the range scope may be raised or lowered as the operator desires, by means of this control.

Ad-6. *Oscillator adjustment oscilloscope* (the 2inch oscilloscope): the scope used to indicate when the calibrating oscillator is adjusted to the right frequency (so that the range marks will have the proper time interval). Control S-6 must be in position 3 for any picture to appear on this scope.

Ad-7. *Oscillator ad just meet oscilloscope focus*: permits focusing the picture on the osc. adj. screen.

range corresponding to step position on the scope when control S-4 is in position C (or for a 375-mile nominal range).

Op-5. *Range step control*: this knob controls the position of the step on the range scope, and the corresponding reading of the numbers on the range counters.

Op-6. *Bearing indicator*: indicates the direction of antenna train, with the outer dial indicating the relative hearing, and the inner dial the true bearing (if control S-1 is in TRUE position and gyro compass is operating properly). Two diamonds, or bugs rotate with the antenna; the orange bug should he read when adjusting for the maximum pip, and the

Ad-8. *Cal. osc.*: controls the time interval between the range marks (by controlling the frequency of the calibrating oscillator). This, of course, changes the picture on the osc. adj. (Ad-6).

Ad-9. *Cal max.*: controls the speed of the sweep (travel of the spot of light across the screen) on the range scope. Changing this speed gives the appearance of crowding the range marks closer together, or spreading them farther apart.

Ad-10. *Cal min.*: permits moving the range step along the time base without moving the range counters, so that the range counters will indicate the correct range.

Ad-11. *Dimmer*: adjusts the brightness of the dial lights.

4-SA-4

SA RADAR

Ad-12. *First R.F.*: receiver tuning adjustment.

Ad-13. *Second R.F.*: another adjustment of the receiver tuning.

Ad-14. *Osc.*: tuning control of the "local oscillator." Another receiver tuning control.

Ad-15. *Ant.*: adjustment to tune the input circuit to the receiver.

Ad-16. *Calibration chart*: lists settings which are approximately correct for controls Ad-12, Ad-13, Ad-14, Ad-15. *These four tuning controls should he adjusted for the greatest echo strength.* (There are four sets of settings-only one will be correct for a particular radar set. The technician decides which set of readings to use.)

3. Alter about 30 seconds, a relay will snap in the TCA.

4. Now snap transmitter power switch ON (up). The plate current meter should light up.

5. While watching the plate current meter, turn the plate voltage knob clockwise until the meter shows a sharp dip. Continue raising the plate voltage until the 5-7 milliamperes is read on this meter, or until the present stop is reached. If the overload relay trips while doing this, it may he necessary to lower the plate voltage, reset the relay in the transmitter (click emergency switch on the transmitter off, then on again), and continue operation, using a lower plate current.

Turning off.

Ad-17. *IFF gain*: the "volume control" of the IFF receiver, since it adjusts the size of the IFF pips on the range scope screen as the operator desires.

Ad-18. *L.R. amp*: controls separation of the two blips from a target when using lobe-switching. To he effective, control S-7 should he ON, and L-R off in the ON position.

Ad-19. *Duplexer adjustment* (on transmitter) tunes the duplexer (a part of the antenna connections).

Alarms.

Al-1. *Bearing mark*: a push-button which rings a buzzer on the bridge when the operator wishes to call attention to the remote bearing repeater.

Al-2. *Range mark*: sounds alarm at the remote range repeater to call attention to the range indicated.

TURNING ON AND OFF

Turning on.

1. See that these controls are in the proper position.

    a. Transmitter power OFF.
    b. Slewing motor OFF.
    c. L-R motor OFF.
    d. Emergency train-AUTO.
    e. Antenna train-TRUE (if ship's gyro compass is operating properly).
    f. Plate voltage control fully counterclockwise.
    g. Receiver gain down (fully CCW).
    h. Intensity down (fully CCW).

2. Snap on the main power-emergency switch. The dial light on the line voltage meter will come

1. Turn plate voltage variac fully counterclockwise.

2. Snap transmitter power switch to OFF position.

3. Turn off main power switch.

CALIBRATION

1. If the cal-synch switch is in position 2 and cal-fid-IFF is in position 2, 3 or 4, the transmitter pulse will be visible on the scope when gain is increased.

2. Snap cal-fid-IFF switch to cal (No. 1) position and cal-synch switch to position 3. The trace will disappear from the range scope. Adjust focus (No. Ad-7) control until some indication appears on the 2-inch scope.

3. Now adjust cal-osc control until a stationary pattern appears on the 2-inch scope. Either a figure eight pattern or a horizontal V is satisfactory.

4. Then turn focus (No. Ad-7) control so that this picture disappears and snap cal-synch to position 2. Range marks should again he visible on the range scope. Snap range selector switch to the A position (30,000 yards).

5. Set the range counters to read precisely 6,000

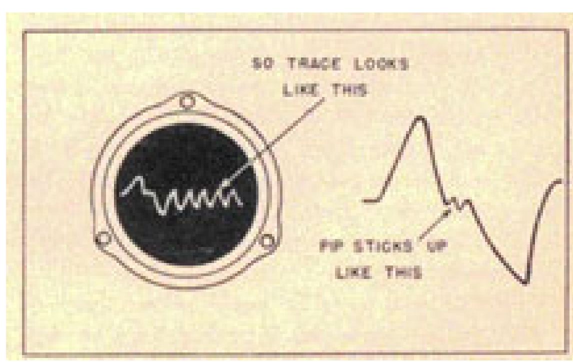

Figure 4 SA-3. Pattern for calibrating minimum range on 15,000-yard scale.

on. Adjust line voltage control so that this meter reads 115 volts, The blower motor in the transmitter will start, and the red lights on the TCA and the transmitter will go on.

4-SA-5

RADAR OPERATOR'S MANUAL

yards; next adjust cal-min so the step is accurately aligned with the beginning of the second range mark. This adjustment is correct when the little peak just beyond the right-hand end of the first range mark is leveled up with the end of that mark (at the beginning of the second range mark). (see fig. 4 SA-3.)

6. Adjust cal-max until the counter reads 26,000 yards when the step is lined up with the beginning of the seventh range mark. (sec fig. 4 SA-4.)

7. Repeat steps 5 and 6 until no further adjustment is necessary to make the step read correctly at either end, then snap cal-fid-IFF switch to position No. 2.

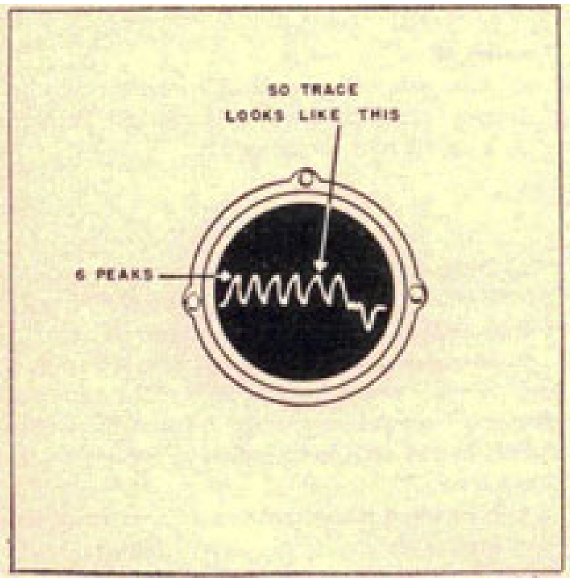

Figure 4 SA-4. Pattern far calibrating maximum range an 15,000-yard scale.

OPERATIONAL TECHNIQUE

vertical control until the trace appears directly above the scale.)

Now begin to search by starting the antenna rotating either automatically or manually.

Miscellaneous adjustments.

If lobe switching is to be used, turn plate voltage control completely down (counterclockwise), snap L. R. motor on (either to right or left), and wait one complete minute before again raising the plate voltage, except *in emergencies*; the voltage may be raised after about 30 seconds. Snap L.R.-off switch to ON position (No. 1) and adjust L.R. amp. control until the traces are separated suitably. While matching pips, read the white bug.

If IFF equipment is used with this set, turn the IFF equipment on, snap cal-fid-IFF switch to position 4, and adjust IFF gain until a reasonable amount of grass appears below the time base, then set cal-fid-1FF back to either position 2 or 3 until ready to challenge a target. Snap cal-fid-IFF switch to position A to challenge a target.

Long-range search.

The SA radar was designed primarily for long range air search-an early warning of approaching aircraft. Its effectiveness depends not only on the materiel condition of the equipment, but also on the efficiency of the operator. The following search procedure permits the set to be used efficiently and effectively.

Tuning the receiver.

Increase the receiver gain until some grass appears. If any targets are present, adjust OSC., 2nd R.F., and 1st R.F. controls until the pip appears largest. *Unless some target is present to tune on, this step should not he attempted*. Sea-return is a "target," if visible, and you can tune on it-using the short range scale. If no targets are available, and set is *known to be out of tune*, set controls as listed on the calibration chart (Ad-16).

Move the step until the range counters read 40 miles. If the step is not accurately lined up with the 40-mile mark on the transparent-tape scale, adjust horizontal centering control until it is. (Operate

Search first on the 75-mile scale, using low speed automatic antenna rotation. Keep the gain fairly high (at least one-sixteenth of an inch of grass), and watch for very weak pips. The lobing motor (L.R. motor) should be kept off. Continue searching on this scale and in this manner for about four minutes, then make one or two complete rotations of the antenna using the manual antenna control, studying the trace very carefully.

Next switch to the A-scale (30,000 yards), and search for two complete antenna rotations, looking especially for small pips which may not have been on the B-scale. Use manual rotation of the antenna for the second turn of the antenna. Readjust the gain and astigmatism controls slightly, if a clearer, sharper trace is desired. Low flying planes may be detected first on this scale.

Again search on the B-scale for about five minutes, as outlined above.

Then use the C-scale (375 miles) for two rotations of the antenna, using *manual* control. Pay particular

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attention to the left-hand portion of the time base. Again readjust gain, astigmatism, and intensity controls slightly, if necessary. Repeat in order, the steps outlined above.

The procedure described above must be used when operating independently. A somewhat different procedure is required when serving as radar guard ship. In this case, the O.T.C, will state whether search should be made using only the 75-mile scale or only the 30,000-yard scale. The antenna should not be stopped on a target except for a few seconds (while challenging for IFF, etc.), without specific instructions from the O.T.C.

the bug. For each individual, this time is practically constant; in other words, the *bearing error will be practically constant*. When an operator determines the magnitude of his individual "error" he can read the bug, correct for his "error" and report the corrected reading. An example will serve to make this clear.

Assume that the operator has the antenna set for low speed automatic rotation, clockwise, and knows that the antenna rotates nine degrees after the pip first begins to drop off in height, and before he can read the bug. He watches the pip increase in size, and then begin to drop off, he immediately reads the

Searching over land.

If search must he made over land, target pips will be mixed with the land pips. However, planes will give echoes which bob up and down more rapidly and irregularly than the land pips. Also, the plane pips will move with respect to the land pips. When faced with the problem of searching over land, the antenna may be stopped for a few seconds to determine whether the pip is actually behaving as a plane echo or as a land echo. Bearings cannot be obtained very accurately, but the bearing of *maximum swing* of the pip should be reported. Land masses may cause the pip to be higher on a bearing a few degrees to one side of the actual target bearing, and so maximum pip height *may* not give the correct indication-it is the maximum bounce that counts. The approximate bearings secured are well worth the effort expended to get them.

The operator must remember to keep searching. He should *not* find one target and "camp on it" from then on.

Reading bearings on the fly.

With practice, almost any operator can read the bearing of an object with considerable accuracy even though he does not stop the antenna. This speeds up tracking and makes the SA radar much more effective.

Any experienced operator can tell when the pip on the scope first begins to drop off as the antenna scans past the bearing of the target. If he then glanced at the bearing indicator and read the bearing indicated, he would be reading a bearing somewhat large (for CW rotation of the antenna), because of the delay before reading the bearing. The size of the error involved would depend upon the time required by that particular operator to realize that the pip height had begun to drop off bug, silently. If he read "one-nine-seven," he would subtract nine degrees (his "personal error") and call off "one-eight-eight."

When the pip first appears, the range can be read immediately and remembered. As soon as the bearing has been reported, the operator can call off the range without hesitation and with no need of again looking at that pip until the antenna gain approaches the bearing of that target. With practice, this reporting procedure becomes almost automatic.

Operators must make every effort to learn this method of reading bearings. They must practice until the delay in reading is unchanged each time they report. (In other words they must not slow down or speed up glancing from the scope to the bug.) To find their own lag, they should first watch the pip grow in height, read the bug, and then use lobe switching to find the *accuracy* bearing. Comparing these two readings will indicate the amount of correction to be applied each time. This must be repeated over and over again, until the operator gets the same correction (within a degree or so) each time.

This is not as difficult as it sounds. It does take practice, but results are well worth the effort involved.

Tracking.

Targets probably will be contacted first on the 75mile range scale; hence, this is the scale most often used for tracking. The addition of a transparent tape range scale to the scope, makes accurate tracking of several targets relatively quick and simple. Tracking while using this 75-mile scale will he discussed first.

When a pip appears, stop the antenna approximately on the target, but do not waste time getting an accurate bearing. Read the bearing indicated by the

and then to look at

orange bug, and note the range indicated on the

scale marked on the front of the scope. (Do not use the range step.) If the plane is close on initial contact, you can save valuable time by reporting it as a *bogey* without interrogating first. The next time around, interrogate, estimate composition, get accurate bearing and range, and see whether they are opening or closing range, or crossing. Report. Snap cal-fide-IFF switch to position 4 to check for IFF-response.

When the contact is identified as *friendly* or *bogey*, start the antenna rotation at slow speed, automatic, and continue searching for other targets. When the pip from the first target reappears, note the range immediately from the scale on the scope, and read the bearing "on the fly." This report should be made every time the pip appears, reporting the bearing first and then the range.

Keep in mind the number of targets present, and if one fails to appear when the antenna scans past its previous bearing, report it as being "in a fade."

Generally speaking, there is no reason for changing from the 75-mile scale while tracking. Even after a plane, or group of planes, has closed well within 30,000 yards, the 75-mile scale is still sufficiently accurate and much more easily read than the 30,000-yard scale,

If a target is first discovered at a range greater than 75 miles, tracking must be conducted using the 375-mile scale. This requires stopping the antenna on the bearing of the target and using the range step, then starting the antenna once more. When the target closes to within 75 miles, use the 75-mile scale, as explained above.

Also the antenna must be kept bearing on the target. The operator does this by keeping the two pips from the target matched in height; it may be necessary to reduce the gain to keep these pips below saturation. He keeps the two steps lined up with the two pips, and reads the ranges indicated on the counters.

The actual tracking procedure would be for the plotter to call "stand by" every 25 and 55 seconds after the minute, followed by "mark!" on the minute and half-minute. The operator should read *true* bearings as indicated on the inner scale by the *white* bug during the tracking. When directed, to do so by the CIC evaluator, he should report ranges, *relative* bearings, and read the enter dial, to the gunnery officer. He should read these ranges and bearings continuously.

Jamming and deception.

There is no doubt that the enemy considers our radar an extremely dangerous weapon, and consequently it is only reasonable to expect him to try every means possible to make it less effective. He may use two tactics to do this: jamming and or deception. Every operator should learn how to recognize these countermeasures, and expect them when in combat zones.

When the enemy broadcasts radio signals intending that our radar receive them, and they show a confusing pattern on the screen, it is called jamming. Use of dummy targets (tinfoil, kites, balloons, etc.) is called *deception*. Of course, more precise definitions are sometimes given, but these are satisfactory for this discussion.

The SA radar can be jammed, and it will show

If a plane is discovered while searching on the 30,000-yard scale, give the initial contact report and continue searching. If the pip can be seen clearly on the 75-mile scale, that scale should be used in tracking. Search *must* be continued while tracking air targets.

Fire-control liaison.

Use of the SA radar for antiaircraft fire-control is limited to warning of the approach and tracking the targets (getting course and speed). However, this radar is useful in surface fire-control work, for it gives ranges and bearings which may be used in an emergency for this task. In any event, it gives information sufficiently accurate for star shell illumination of surface vessels.

When the SA radar is used for this work, lobe switching should be employed and ranges read from the 30,000-yard range counter.

echoes from the tinfoil the enemy sometimes throws out to confuse the operator. The operator should not become alarmed when either of these things happen.

If you were suddenly confronted with jamming, without previous experience, it would appear impossible to work through. However, it is not really that serious if the following procedure is carried out:

1. DF on the jamming.
2. Use available anti-jamming devices on receiver when provided.
3. Try moving gain control up and down.
4. Try changing receiver local oscillator toning.
5. Keep operating.
6. Report type and bearing of jamming to CIC.

The first reason for obtaining a bearing on the jamming is to determine whether or not it could be accidental interference. Jamming will not only be

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directional, but its true bearing will not be changed by any sudden change in your ships course. Interference originating aboard your own ship will either be non-directional and appear on all bearings, or else it will always be on some certain relative bearing regardless of your own ships course changes.

Try moving the gain control up and down. This is probably one of the most important countermeasures that can be taken, and the one most commonly overlooked because of its simplicity.

In most cases, except when effective noise modulated jamming is being encountered, there is change from time to time, so if you are persistent enough some information may be obtainable.

Report nature and bearing of jamming to CIC. Recognizing the type may be difficult because nonsynchronous patterns sometimes appear blurred beyond recognition. Inasmuch as knowledge of jamming types* may possibly help identify the jammer in some cases, this information should he reported.

If the equipment is provided with an anti-jamming receiver, the jamming may he reduced sufficiently for reading targets without any detuning of the receiver. Detuning should be a last resort, and then should he done very carefully and cautiously,

a setting of the gain control with which it is possible to range on a target in the presence of heavy jamming. If there are several echoes on the same bearing, the best setting for each echo is different. Of course it is more difficult to obtain these ranges because of the distortion of the echo produced by jamming, but it is, after all, possible to obtain the desired information. However, the extra effort is worth while because the enemy would not be jamming unless he were trying to conceal something important.

The two general methods of using the gain control, both of which should be tried, are as follows:

a. Reduce setting; this prevents overload of the radar receiver; echoes are visible "riding on top" of the jamming pattern.

b. Increase setting; this limits (or clips) jamming; echoes are visible as a break in the base line.

Be sure to return the gain control to its normal setting when no jamming is present, or when the antenna is turned to an unjammed bearing.

Try changing receiver local oscillator tuning. When you change the oscillator tuning, you lose some of the height of the desired echo. However, if the jammer is not exactly on your radar frequency, there is a chance that you will detune the jamming signal more than the echo signal. Considerable improvement can sometimes be obtained this way. Try "swinging" the oscillator tuning dial in both directions, to see which direction makes the greatest improvement. Note the correct setting of the oscillator dial so that it can be returned to its normal position when no jam is present, or if detuning does not help, otherwise the radar will not give optimum performance.

otherwise all targets may be lost and the equipment made completely ineffective. No set procedure is offered for setting the controls of the AJ receiver, except that they should be varied for maximum readability through jamming, the gain control coming first, and then the AVC control followed by Rej 1 and Rej 2.

Above all, never off the radar.

When jamming/and or deception is encountered, full 360 degrees search must be continued. However, the antenna should be stopped for short intervals from time to time in order to try reading through the jamming (using the "A" scope). You also must be prepared for any diversionary tactics, for the enemy may or may not use jamming and or deception to divert your attention from the bearing of the main attacking forces. This problem is simplified somewhat when similar but separate radars are used for reading through jamming and for searching.

PERFORMANCE

Maximum reliable range.

Antenna 89 feet

Target

BB, CV. CB, Large auxiliary	43,900 yards
CA, CL, Medium auxiliary	24,900 yards
DD, DM, AU, PC, CG, etc	15,600 yards
Submarines (surfaced)	4,500 yards
Large planes-PBM, PB2Y, PBY	40 miles
Small planes-SOC, SBD, F6F	20 miles
Groups of planes	60-80 miles
Land (1,500 feet or higher) depending on atmospheric condition	90-200 miles
Low flying planes	10-15 miles

Even if the jamming is extremely effective keep operating. Don't turn your radar off. Turning your radar off informs the enemy that his jamming is effective, and certainly makes the radar completely worthless. The effectiveness of the jamming may

* See Part 3, Defense Against Jamming and Deception.

Minimum range.

Ships-depends on sea-return	750-2,000
Planes	1.0 mile

Range accuracy.

When using the step and the 30,000-yard scale, the accuracy is about +/- 100 yards. When using the 75-mile scale and reading ranges from the transparent tape, the accuracy is about +/- 1.0 mile.

Bearing accuracy.

With lobing +/- 1 degrees
Without lobing +/- 3 degrees - 5 degrees

TROUBLES

Probably the most frequent failure of SA equipment, is the failure of the oscillator tubes in the transmitter. The operator can easily recognize this because the plate current meter does not show a dip when the high voltage control is turned up. One, or both tubes must be replaced when this happens. Usually, failure will be gradual. The operator should notice when the plate current rises more rapidly than it does normally as the high voltage is increased, since this indicates that the tubes are going bad. The small white spot on the high voltage knob (No. P-6), indicates how high

Another common fault is called multiple pulsing. The trace appears to flicker and jump, especially when using the 375-mile scale. Sub-multiple pulsing is indicated when the normal opening below the pip is closed by a bright line.

When signals appear very weak, or when no targets appear, even though land or other objects are in the vicinity, a receiver tube may not be working. The transmitter pulse may appear at its "normal" strength, even though one of these tubes is not functioning, but echoes will not appear.

If the antenna fails to rotate when either the manual control knob is turned or when the automatic control is on, the train control amplifier probably is not operating properly.

Sometimes one or both of the 5 amp. fuses (No. P-7) will open. When this happens, no power can be applied to the lobing motor (L-R motor), or to the automatic antenna train motor. The ten amp. fuse (No. P-8), near the dimmer control carries power to the indicator unit. If the trace should suddenly disappear from the indicator screen, and the dial lights go out, this fuse has probably blown.

If the ship's gyro compass should fail, immediately throw antenna train-relative, true switch to relative position.

If the bug fails to move when either the manual or

the high voltage has been raised.

automatic antenna rotation controls are used, snap emergency train switch to either CCW or CW position.

PART 4

SL RADAR

RADAR OPERATOR'S MANUAL

SL RADAR

CONTROLS

Power controls.

P-1. *Power*: controls all power to the set (except heater power) . Power is off when this switch is snapped to the left (or to the right on some models).

P-2. *Load voltage meter*: indicates the voltage applied to the set.

P-3. *Line voltage adjustment*; an adjustment of the load voltage (the transtat). (Adjustment governs reading of load voltage meter.)

P-4. *High voltage*: this switch turns the high voltage on or off: ON to the right. OFF to the left.

P-5. *Mag. or conv. current*: current: this meter indicates either the magnetron current or the converter current, depending on position of the ammeter-mag. conv. switch.

P-6. *High voltage adjustment*: this controls the amount of voltage applied to the transmitter. (It is called the variac. Setting of this control governs reading of the ammeter when in mag. position.)

P-7. *Drive motor*: this switch controls power to the antenna drive motor and to the indicator motor rotating the sweep (in synchronism with the

When the switch is snapped to the right, the antenna and the deflection coil (around the PPI) rotate et 18 rpm.

Selector switches.

S-1. *Range*: a three-position switch, permitting use of one of the three range scales provided: 5 miles, 25 miles, or 60 miles.

S-2. *Ammeter-mag. conv.*: a switch which permits use of the same meter to indicate either magnetron current or converter current.

S-3. *Warning*: a switch used to operate a warning bell or buzzer at some remote location, to attract attention to the remote PPI scope.

S-4. *IFF-off, on*: this switch applies power to the interrogator (if one is attached).

S-5. *Compass-on, off*: (Under indicator panel -below cony, current meter) in the ON position, this switch permits connecting the gyro compass to the radar so that true bearings will be indicated, regardless of the changes in ship's heading. If relative bearings are desired (or necessary, due to failure of the gyro compass), this switch can be turned to the OFF position, disconnecting the gyro compass.

antenna)

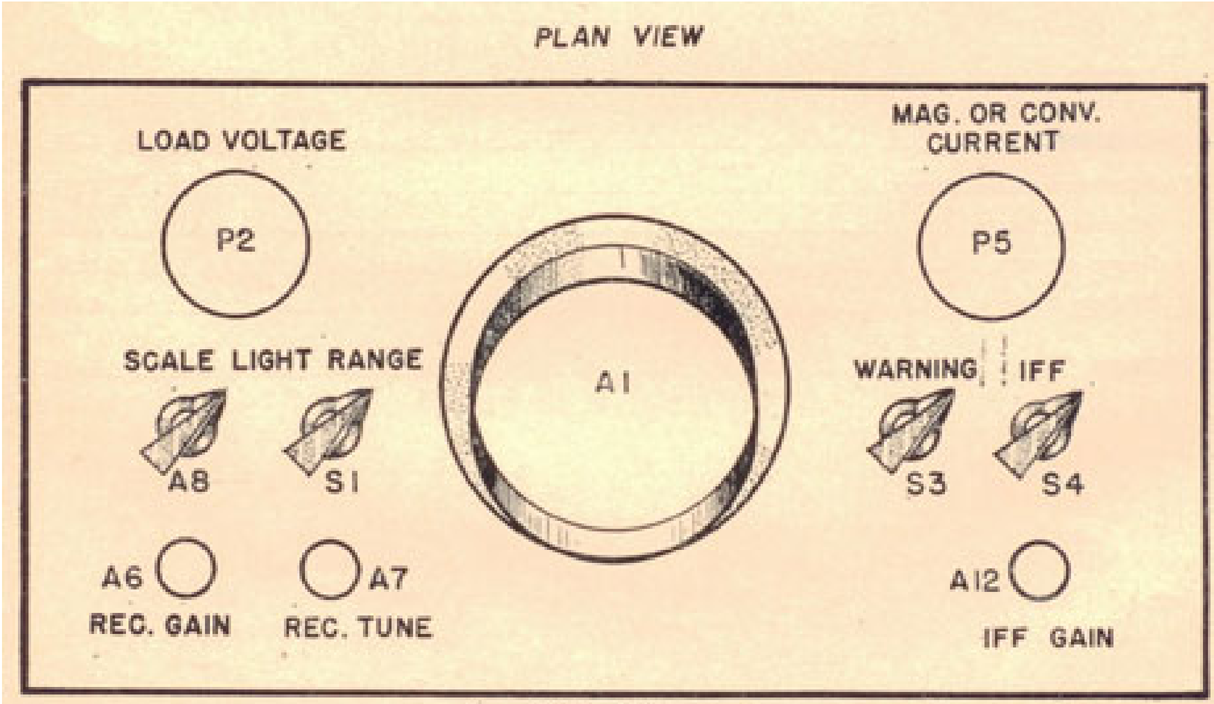

Figure 4 SL-1. Indicator panel.

4-SL-2

SL RADAR

Adjustment controls.

A-2. *Brightness*: a screwdriver adjustment of the over-all brilliance of the trace on the screen.

A-3. *Focus*: a screwdriver adjustment to bring the sweep into a sharp, clear, and even line.

A-4. *Horizontal centering*: a screwdriver adjustment shifting the complete picture on the scope to the right or left.

A-5. *Vertical centering*: a screwdriver adjustment shifting the complete picture on the scope up or down.

of the azimuth mark (indicates relative bearing of the antenna at 000 degrees. when properly adjusted).

A-10. *Range mark*: controls the brightness of the range mark which should appear at the outer edge of the scope.

A-11. *Retard: indicator, antenna*: these push button controls permit setting the azimuth mark to any desired direction on the screen (to 000 degrees when *relative* bearings are to be read, and to the ships heading when reading *true* bearing).

The indicator button stops the indicator while the antenna continues rotating, and consequently makes the azimuth mark move counterclockwise.

The antenna button retards the antenna without stopping the indicator, and this makes the azimuth mark move clockwise.

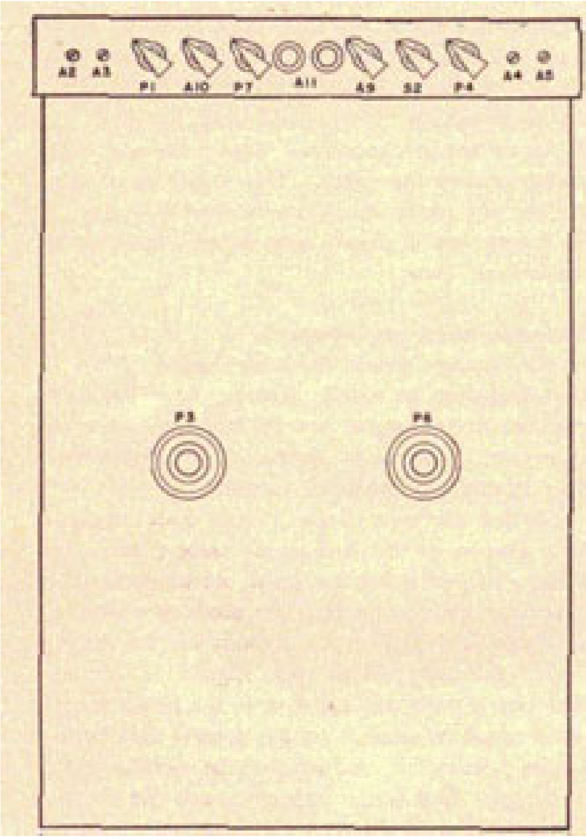

Figure 4 SL-2. Indicator modulator assembly.

A-6. *Receiver gain*: this is the volume control of the receiver, and as such, it controls the brightness of the echoes on the scope, and in addition, the brightness of the time base.

A-7. *Receiver tune*: this permits accurate tuning of the receiver to the transmitter frequency so that echoes may be received.

A-8. *Scale light*: permits the adjustment of the brightness of the dial lights on the meters and behind the amber shield over the scope.

A-9. *Azimuth mark*, *increase*: controls the brightness

A-12. *IFF gain*: controls the strength of IFF response applied to the SL screen.

TURNING ON AND OFF

Turning on.

Check controls for normal positions:

1. Rec. gain-CCW.
2. Azimuth mark-CCW.
3. Drive motor-off.
4. High voltage switch-off.
5. High voltage adjustment-full CCW.

Power adjustments:

1. Turn power switch ON. The dial lights should come on and a motor should begin whirring inside the modulator unit. The scale light control should be adjusted to suit the operator.

2. Adjust the line voltage adjustment until load voltage meter reads 115 volts.

3. Snap the high voltage switch ON and wait for a loud whistling tone (the 800-cycle note). A time delay relay, requiring about one minute to operate, must close before the 800-cycle note will start. As soon as the whistling starts, check the ammeter reading with the ammeter switch in mag. position. if reading is less than 10 milliamperes, turn off the set and call the technician; if above 10 milliamperes, readjust line voltage control until load voltage meter reads 115 volts. Adjust high voltage control until the magnetron current is 15 to 19 milliamperes.

4. Turn drive motor on and listen for grinding of gears.

RADAR OPERATOR'S MANUAL

Turning off.

1. Turn rec. gain fully CCW.
2. Turn azimuth mark fully CW.
3. Turn high voltage adjustment CCW.
4. Turn off high voltage switch.
5, Turn off drive motor.
6. Turn power switch off.

CALIBRATION

Calibration should he checked by turning the range mark control fully clockwise. A bright spot will then rotate at the end of the trace line, around the edge of the PPI screen. If the circle drawn by this spot lies below the outer circle on the plastic scale, the calibration is correct. If the calibration is off, adjust the screwdriver adjustment, sweep length, which is underneath the indicator cover, until it conforms with the correct calibration.

OPERATIONAL TECHNIQUE

Preliminary operational adjustments.

Turn the azimuth mark increase clockwise, and set the position of the azimuth mark by operating the retard- indicator, antenna. If *relative* bearings are wanted, set the azimuth mark to 000 degrees; if true bearings are desired, set it to indicate the ship's heading at that moment. (Compass switch must be in compass position if true bearings are to be read.) Turn the azimuth mark low, but *visible*.

With the rec. gain turned completely CCW, adjust the screwdriver control on *brilliance* until trace barely appears. Increase rec. gain slightly until trace appears clearly, then adjust *focus* control until the trace is a sharp, distinct line. Then adjust the *horizontal* and *vertical centering* controls until the trace starts directly beneath the *center* of the amber shield over the screen.

of the targets. The receiver gain should be adjusted while doing this to keep the brightness low. If no targets are visible, tuning may be done by adjusting rec. tune for maximum sea-return. In case the sea is very calm, and you can not even get a satisfactory echo from your own ship's wake, it is possible to tune the receiver approximately by watching the converter current. This method is to be used as a last resort when no echoes of any kind can be seen.

Set the mag.-conv. switch in the cony. position and adjust rec. tune control for maximum meter reading, from .4 to .8 milliamperes. Be sure to switch mag.-conv. back to mag., the proper position during operation. (Do not attempt to tune the receiver during the 15- to 30-minute warm-up period after turning on the equipment.)

Adjust receiver gain until "snow" appears in the background of the screen. This should be adjusted for the best target indications on tile PPI scope. If no targets are in the vicinity, adjust for noticeable amount of "snow."

Recommended operation.

The operator should check the tuning of the SL on taking over the watch. Tuning should not be attempted unless targets are available, or sea-return is present. Tuning is done by adjusting receiver tune control for maximum intensity.

Normal operation: use 25-mile scale primarily, with gain set so that background noise ("snow") is visible, but not bright enough to obscure indications. Search on the 25-mile scale for about four minutes, then search for about 30 seconds on the 60-mile scale, readjusting receiver gain slightly, if necessary, and paying particular attention to the longer ranges. After about 30 seconds on the 60-mile scale, switch to the 5-mile scale, and readjust the receiver gain if necessary. This is the scale on which the operator

Tuning the receiver.

Set the range selector switch as follows:

1. If at sea, with no objects in the vicinity, or with objects within five miles, set on 5-mile scale.

2. If at sea, and the nearest object is beyond 5-mile range, but still within radar range, set on 25-mile scale.

3. When within 25 miles of land, use 25-mile scale.

Tune the receiver, adjusting for maximum brightness

will detect small objects, close aboard, such as submarines awash. *Report all contacts*.

Station keeping: if radar information is needed for station keeping, the receiver gain should be reduced sufficiently to show ships in formation clearly. Do this immediately after completing the 30-second search on the 5-mile scale, then switch to the 25-mile scale, and repeat the cycle.

Submarine contact: after sound contact has been made with a submarine, or when such contact is probable, you should operate primarily on the 5-mile scale, with the gain sufficient to bring out some background noise. (Remember, unless the gain is up, small targets will *not* be seen.) Look for a short,

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faint arc or spot, which recurs at the same spot for two or more successive rotations of the antenna. (Snow splotches will not repeatedly appear in the same place, while indications from targets will.) Every three minutes, reduce the gain and search for pips near the center. These *might* have been masked by the sea-return while the gain was high. Search in this way for about 30 seconds.

Surface contact: operation after contact with the surface target is made, including surfaced submarines or submarines awash.

The recorder shall call "stand by" five seconds before "mark" is called. If a single target is being tracked, "mark" should be called every minute (unless the 60-mile scale is being used, then "marks" are given every two minutes). If two targets are being tracked, one should be called on the minute, and the other on the half-minute, thus

Jamming.

Jamming is deliberate interference, caused by the enemy, which limits the effectiveness of your radar; or it is interference produced by our ships to limit the effectiveness of enemy radars. There are several types of jamming, but all are characterized by some strong form of interference pattern on the indicator. These interfering signals are directional in nature, and the bearing or bearings from which they come, can be easily found by looking down the center of the lamming pattern. The jammer does make it difficult or impossible to read range, but effective jamming is not easy for the enemy to accomplish, and it is apt to disappear momentarily from time to time. Learn to expect it, and be prepared to follow the best course of action when the time comes. Do not mistake interference created aboard your own ship, or trouble in the radar set for jamming, the real thing will be directional, and its true bearing will not

each target is "marked" at one minute intervals. Operators will call off bearing and range of target when "mark" is called.

If target is beyond the 5-mire range, but nearer than 25 miles, normal search routine should be followed, except for the reporting of targets every minute. A "mark" might be missed while searching on the 5-mile scale, but this is not serious, If "mark" is called while on the 60-mile scale, the operator may call the bearing and ranges from that scale. This point however, should not be used in determining course or speed.

If the target is within a range of 5 miles, search should be continued on the 5-mile scale primarily, switching to the 25-mile and 60-mile scales for 30 seconds each after 4 minutes on the 5-mile scale. Possibility of contact with other units must not be overlooked.

If the target is first detected at a range greater than 25 miles, the 60-mile scale should be used primarily, until the target has closed to within 25 miles, Search for four minutes on the 60-mile scale, then switch to the 25-mile scale, for about 30 seconds, and the 5-mile scale for about 30 seconds. Recorder should call "stand by," followed by "mark," every too minutes while reading from the 60-mile scale.

Clouds: echoes from clouds are often seen on the radar screen. Operators usually can recognize these as such, because of their distinctive appearance. Occasionally, however, this distinction cannot he made, and the cloud echo will resemble a ship echo closely. The operator should report them in either case, giving all information he can.

change immediately when your own ship changes course.

As you approach the jammer, the radar echoes from the jamming ship (if it is sea-borne) will increase in strength more rapidly than the jamming signal, and you stand a good chance of being able to read range through the interference. See part 3, Defense Against Jamming and Deception.

When jamming occurs:

1. Get the bearing and report it.

2. Keep operating the set and try to read the ranges through the interference. Try various settings of gain control. There is a chance the jamming will stop long enough for you to get range.

3. Keep reporting its bearing periodically.

4. Be ready to turn on a radar which operates on a different frequency band if ordered, provided that you have one,

5. Draw a picture of the jamming pattern while it is fresh in your memory, and send it to the Bureau of Ships without delay.

PERFORMANCE

Maximum reliable range.

The higher the antenna, the greater the maximum range; for this reason, performance figures are given on the following page for several antenna heights.

RADAR OPERATOR'S MANUAL

Target	**Maximum Reliable Range in Miles**		
	53 feet	*69 feet*	*85 feet*
BC, CV, Large auxiliary	13-15	19-21	21-23
CA, CL, Medium auxiliary	12-14	16-18	17-19
DD, DE, DM, AV, CG, etc	10-12	11-13	13-15
Submarine on surface	3-5	9-11	6-8
Submarine periscope	2	2	?
Buoys	?	3-4	3-4
Large aircraft below 3,000 feet	14-20	14-20	14-20
Small aircraft below 3,000 feet	9-13	9-13	9-13

Minimum range.

The average minimum range for ship targets is about 500 yards (1/4 mile), and on aircraft targets about 700-1,000 yards. These figures will be somewhat higher when sea-return is strong.

Range accuracy.

The figures for the possible error of the set, plus the probable error of estimation are approximately:

5-mile scale	+/- 500 yards or +/- 1/4 mile
25-mile scale	+/- 1,000 yards or +/- 1/2 mile
60-mile scale	+/-2,500 yards or +/-1 1/4 miles

Bearing accuracy.

Approximately +/- 2 degrees - 3 degrees

TROUBLES

Inferior performance of the SL radar can be

this condition, but if that does not help, you should notify the technician.

Sometimes, echoes will look scalloped, and the "snow" will appear in fan-like streaks radiating *straight* out from the center of the screen. When this occurs, it is an indication that the set is being keyed improperly; the technician should cheek the spark wheel electrodes. This trouble will also he revealed by a spitting noise, or an unsteady whistling from the modulator unit.

If the modulator whistles normally and the converter current is normal, but the magnetron current reads zero, either the pulse cable or the pulse transformer is faulty, and the technician should be notified immediately. No echoes will appear on the scope until the failure is corrected. When the bright spot of the transmitted pulse appears on the scope along with some "snow," but no echoes appear, check both magnetron current and converter current for normal readings. If they are working properly, a receiver rube is probably faulty; ask the technician to replace it.

If the equipment is set to indicate true bearings, and the azimuth mark does not change bearing when the ship changes course, the gyro compass may not be functioning. This fault may also be indicated by

recognized by the operator paying close attention to the indicator screen, the mag., cony. current meter, and by listening to the 800-cycle note of the spark gap keyer.

If the set is not tuned properly, targets will not appear on the screen with their usual intensity. Consequently, targets may approach your Ship considerably nearer than usual before they are first detected. Sea-return may he dimmer, and more reduced in area than you would expect, considering the condition of the sea. In general, echoes look normal except that they appear weaker than usual or reduced in size. You should try retuning the receiver whenever you observe drifting of the azimuth mark and target indications on the screen. If the fault is not with the gyro, the trouble may arise from a slipping clutch. If the gyro compass is not functioning, you should request permission to switch to relative bearing, and do so by snapping the control switch (compass on-off), beneath the indicator panel, to OFF, and by setting the azimuth mark to 000 degrees.

PART 4

SO RADAR

4-SO-1

SO RADAR

CONTROLS

1. *Off-on*: this switch controls line voltage to the motor starting relays, blower, protective solenoid, and synchro phasing relay circuit. This switch is not used on the SO-1 and SO-2 radars. A separate bulkhead switch (18) is mounted near the plan position indicator to be used instead of 1.

2. *N E*: this is a normal-emergency switch which will be in the N or normal position during ordinary operation. There is a protective thermostat in the transmitter unit, which will turn the transmitter off if its temperature gets high enough to cause possible damage. If this should happen at a time when the radar must be used in spite of possible damage to the equipment, it can be started again by keeping the start button (4) pressed while turning the N E switch (2) to E, the emergency position. If the stop button (4) or the off-on switch (1) or the bulkhead stop button (18 used with SO-1, SO-2, SO-8) should be operated, the set will be turned off and high voltage can not be applied again until the N E switch (2) is returned to N, and the procedure for emergency operation described above is repeated.

5. *Humidity indicator*: when this becomes pink, the technician knows that the dehydrators are saturated with moisture.

6. *S W L*: a screw driver control of sweep length. Sweep length may be varied to show a minimum of three range circles, and a maximum of six range circles.

7. *Range selector switch*: the scales are 5, 20, and 75 nautical miles on the SO and SO-A, with 1, 4, and 15-mile intervals between range circles on the respective scales, The SO-1, SO-2, SO-7, and SO-8 have range scales of 4, 20 and 80 nautical miles, with 1 mile between the circles on the 4-mile range, 5 miles between the circles on the 20-mile range, and 20 miles between the circles on the 80-mile range.

8. *INT*: this is the PPT intensity control for adjusting the brightness of the sweep and the range circles.

9. The *PPI* (plan position indicator) tube.

10. The *Cursor*: by means of this the relative bearings of contacts are read.

3. *Pilot*: adjusts the illumination of the bearing scale around the PPI tube (9).

4. *Start stop*: controls the application of high voltage to the transmitter. (Do not confuse this with the bulkhead start stop switch used with SO-1, SO-2, SO-8.)

11. CCW off CW: this is the antenna rotation toggle switch. When in the CCW position the antenna goes counterclockwise automatically at 12 rpm. In the CW position it goes clockwise at 12 rpm. There is no provision for manual rotation.

12. *Focus*: used to focus the PPI tube for maximum definition.

13. *Center*: this control positions the start of the sweep. The sweep can be made to start from

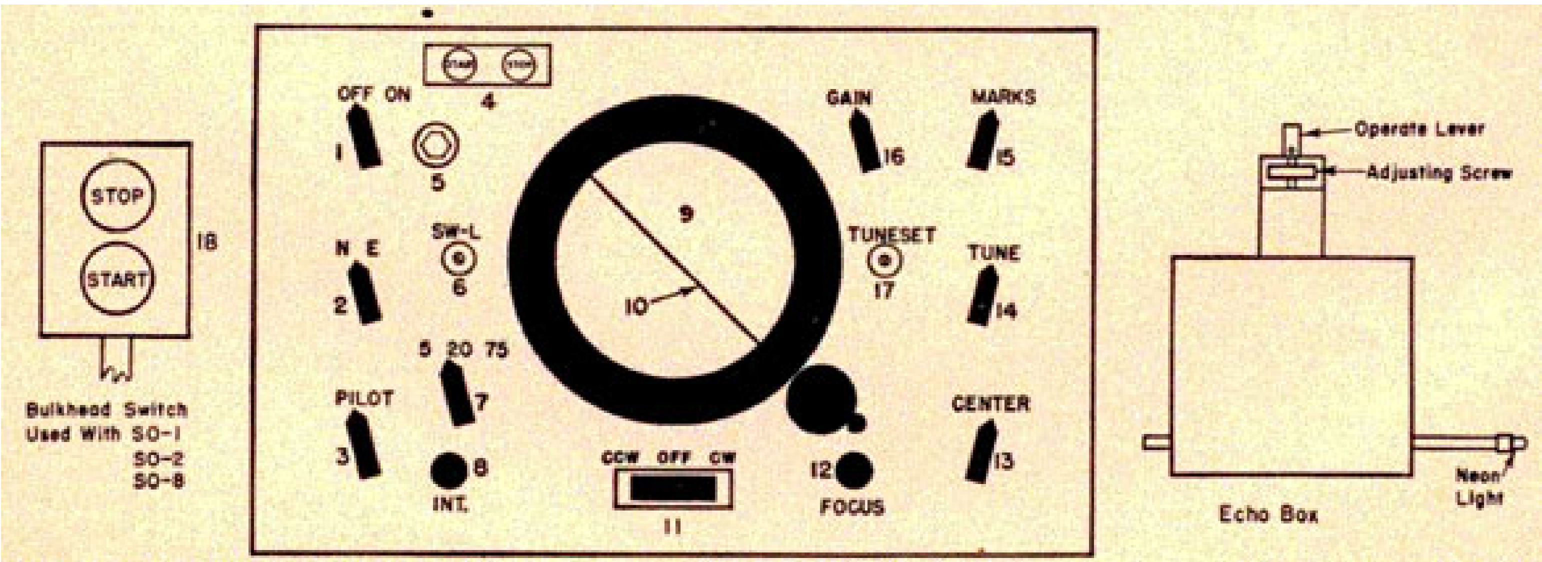

Figure 4 SO-1. Plan position indicator unit.

the center of the PPI, or may be offset from the center as much as a half-inch. This leaves a dark circle in the PPI center which indicates our own ship's position. All contacts move out from the center when the sweep is offset, and it is easier to get bearings of near-by targets. The, calibration of the set is not changed in any way by this control. Normally, there will be a small dark circle about 1/16-inch in diameter at the PPI center.

14. *Tune*: this is the fine tuning adjustment. When it is adjusted for maximum echo brightness, the receiver will be tuned to the

contacts are most likely to be seen. If there are no ship or land targets within radar range, set this switch to short range so that sea-echoes or sea-return may be used for tuning.

10. Turn gain (16) completely clockwise.

11. Adjust tune (14) until contacts or sea-return (echoes from waves nearing your ship) can be seen on the PPI indicator.

12. Stop the antenna on the best contact and adjust tune (1-1) for maximum brightness. If it fails to respond, set tune (14) to mid-position and adjust tune

transmitter.

15. *Marks*: controls the intensity of the range marking circles on the PPI.

16. *Gain*: corresponds to the volume control on any radio receiver, it controls the sensitivity of the receiver.

17. *Tune set*: a rough tuning adjustment. It tunes the receiver approximately to the transmitter. It is adjusted for maximum echo, while the tune control (14) is in the mid-position. This is a semi-permanent adjustment.

18. *Bulkhead stop start switch*, used with SO-1, SO-2, SO-8.

TURNING ON AND OFF

Turning on.

1. Operate NE switch (2) to N. marks counterclockwise, pilot counterclockwise.

2. Be sure INT (8) is turned full counterclockwise; this is done to prevent burning on PPI.

3. Turn off-on switch (1) to ON if an SO. Press start button (18) on SO-1; dial light will come on when turned up.

4. The blower in the transmitter will be heard to start.

5. After two or three minutes, press start button (4), a relay will be heard to click, and the 400-cycle hum will be distinguished.

6. Turn INT (8) clockwise until the trace on the PPI can be seen with moderate intensity. It is set (17) for maximum brightness; then make final adjustment with tune control (14). Tune set (17) is the rough tuning control, and tune (14) is the fine tuning control.

13. With switch 11, start the antenna in automatic rotation again in either direction.

14. Using center control (13) adjust the sweep trace so that the origin is almost in the center of the PPI scope. A small, dark circle, about 1/16-inch in diameter, should be seen at the center of the PPI to assure us that the sweep is not overlapping the center point.

15. Turn marks clockwise until range-mark circles appear on the PPI, and adjust SW-L (16) until 5 range circles show on the SO, or 4 range circles on the SO-1.

10, Note that no calibration is necessary. The set is permanently calibrated at the factory.

Turning off.

1. Operate CCW off CW switch to OFF.

2. Turn INT (PPI intensity control, 8) completely counterclockwise.

3. Turn marks (15) completely counterclockwise.

4. Turn pilot (3) completely counterclockwise.

5. Push stop switch (4).

6. Turn off-on switch (1) to OFF if set is an SO; push bulkhead stop button (18) if set is an SO-1, SO-2, or SO-8, and hold it down several seconds.

Adjusting the echo box.

The echo box furnishes an artificial echo or contact on the PPI indicator, to be used in tuning the receiver

possible to burn the PPI if the trace intensity is too high.

7. Adjust focus (12) for sharpness of sweep trace on PPT.

8. Operate CCW off CW switch (ii) to either CCW or CW, and the trace will rotate on the PPI at 12 rpm automatically.

9. Set the range switch (7) to the range on which when no other radar targets can be found. It can also be used to determine if the transmitter is functioning. Adjustment is made as follows:

1. Put the operate lever in a horizontal position. (See illustration of echo box, fig. 4 SO-1.)

2. With the radar operating, stop the antenna on the bearing of the echo box pick-up antenna; this will be either 000 degrees, or 180 degrees,

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depending upon the type of set you have. Adjust the echo box for the brightest indication from the neon bulb. The glowing of the light indicates that the transmitter is functioning.

3. Put the range switch (7) in short range position. The artificial echo should be seen extending out a mile or two when the receiver is tuned. You may use this echo to tune on, just as you would tune on any echo. Any decrease in sensitivity of the radar will be indicated by a decrease in the range extent of the false echo. On some sets, the echo extends in all directions.

4. To detune the echo box when not in use, pull the operate lever into a vertical position.

OPERATIONAL TECHNIQUE

Reading ranges.

Ranges are read by turning marks control (15) clockwise, until the range mark circles arc dimly visible on the PPI. The range circles are to he interpreted according to instructions already given in the section on Controls (7). Ranges must be read by estimation unless the contact happens to lie on a circle. Estimation of between a contact and its background, and the weakest contacts are seen best in complete darkness.

If you are yawing considerably on your course (as will often be the case on a PT boat), the relative bearing of contacts will be continually increasing and decreasing. For the same reason, contacts on the PPI will broaden into an ill-defined smear when yawing is excessive. If your own ship is steady on its course, bearing accuracy can be as good as +/- 2 degrees or +/- 3 degrees.

When taking bearings of close in targets which appear near the center of the PPI even on short range scale, and with SW-L (6) set for full expansion, it will be found helpful to use center control (13) to de-center the sweep trace, and move the contact out to a more convenient position on the scope.

If the contact is weak, and intensifies only once in several sweeps of the antenna, or if the bearing rate of change is high, it will be found helpful to operate CCW off OW switch (11), so that the antenna moves back and forth over the target instead of making full revolutions. Do not make this sector sweep less than approximately 90 degrees.

Long and short range search.

range is easiest and most accurate when using the short range scale, becoming more approximate as the length of scale increases. When the contact can be read on short scale, its range can be determined to within about 500 yards or a quarter of a mile. The medium range scale can be read with practice to a half-mile, and the long range scale to within about 1 1/2 miles. When not reading ranges, keep the range mark circles off the PPI since they may obscure weak contacts.

Reading bearings.

The bearings blade or *cursor* should be rotated by turning the bearing crank until it bisects the arc formed by the contact. Unless the operator's eye is in the plane of the blade-shaped cursor, a parallax error will result. His eye should therefore see the cursor as a fine line, which is adjusted carefully to the center of the contact. Proper use of the cursor will result in superior bearing accuracy.

When the cursor has been set, turn pilot control (3) clockwise until the relative bearing scale is illuminated sufficiently so that the bearing can be read. When not reading bearings, keep the pilot (dial light control) secured in a counterclockwise position, since the light from the bearing scale destroys the contrast

When long range detection is desired, put the range switch (7) in this position, use full receiver gain (gain full clockwise), and be certain that the receiver tuning control (14) is precisely adjusted. The maximum range at which targets can he detected increases with the size of the target and its presentment. For large ships, the maximum range will be about the same as the line-of-sight distance from the antenna, and can be approximated by the formula d = 1.2 (square root(HA) +square root(HT)); where d is distance in nautical miles, HA is your antenna or eye height in feet above water, and HT is the greatest height of the target above the sea.

If you did not expect to detect even the largest ship beyond 20 miles because your own antenna is low, you should use your medium range scale for long range search and adjust it to show 6 range-mark circles, using SW-L control (6). Under these conditions, you would be able to read ranges much more accurately, and therefore could get a course and speed solution more quickly (from your plot), than if you used long range scale. The formula above will not hold true for small ships or wooden ships since such craft do not reflect enough echo to be detected at maximum line-of-sight distance.

Short range search may he used to detect nearby submarines (if partly or completely surfaced), navigation buoys, small objects in general, and for station

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SO RADAR

keeping. The range selector switch (7) will be on short scale, and the gain control (16) will be turned down (counterclockwise) just enough to rid the PPI of excessive sea-return. Sea-return means echoes from waves near your ship, which causes interference from 3/4 miles to one mile in all directions, in even a moderate sea. With gain reduced, close range detection is now possible down to 200 yards, although the detection sensitivity at longer ranges will be lessened. If a contact is made at close range, it will be seen so close to the center of the PPI that it may be hard to get its bearing with normal accuracy. To facilitate getting a bearing on such a target, de-center the PPI trace by turning center (13) clockwise. The origin of the trace has now moved away from the PPI center, and the contact has moved out a corresponding distance. Its bearing can now be read more accurately. To facilitate station keeping, a dot may be put on the PPI where the guide should be, then when you get off station, the guide's contact will move out from under the spot.

If ships in your convoy or task force, are on stations inside your normal sea-return area, make periodic short range sweeps with the low gain, to see that they are not dangerously close or possibly on a collision course. A ship on a collision course will move down a radial line on the PPI. If a ship is going to execute a maneuver which will bring him close to you, put your cursor on him, if he moves straight down the cursor toward the center of the PPI, something has gone wrong and he is on a collision course with your ship.

False contacts and how they look.

Rain clouds: wide in bearing, deep in range, not sharply defined, with course and speed same as wind.

target to be seen on a wrong bearing; rarely visible, except when many ships are traveling together. These contacts are often distorted, and not as well defined as the usual contact. Their appearance and disappearance is usually related to course changes.

Wakes: always appear as a small contact astern of some nearby ship; they vary in size, becoming largest when the target ship is in a turn.

Whitecaps to windward: sometimes, a contact will he seen just beyond the sea-return area in the direction from which the wind is coming. It will keep the same relative position regardless of course and speed of your ship.

Side lobe contacts: rarely give trouble, but may be seen when good radar targets are at close range. They appear at the same range as some target that is giving a good contact, and come in pairs, one on each side of the true target contact. They are smaller than the true contact, and smaller than might be expected at that range. Operating the set near high mountains may give side lobe contacts, which will be large smudgy contacts on the PPI scope.

Second sweep echoes: you may hear of these, but you will never see one on the SO radar, because their repetition rate is low enough to preclude this possibility.

PPI interpretation.

The radar beam is projected into space in much the same manner as light from a searchlight, and there are radar shadows similar to ordinary shadows. Radar can not "see" through mountains, or behind them, or through any other large obstruction; it cannot see around corners, whether they be formed by headlands or the horizon. For this reason, radar shadows show as dark areas behind high points of land, and in the position of low lying land. Visualize the light and shadow detail presented to an observer looking down

Ionized clouds: not visible to the eye, not easy to identify, often in groups, the course and speed same as wind, upper air will not always move with surface wind.

Floating objects (barrels, cans, etc.) small contact considering the short range, no course or speed.

Double range echoes: caused when returning echo is reflected from own ship, and makes a second round trip to the target, usually seen only when a large ship is close and on a parallel course. Will appear on the same bearing as a large ship, and at twice the range, its range rate will be twice the range rate of the large ship.

Reflection contacts: caused by your own radiated waves being deflected by some object aboard your ship, or another ship, in such a way as to cause a legitimate

from a high position in the sky just at sunset. The lighted areas would be light areas on the PPI scope of a radar, bearing in the direction of the sun from the island, and the shadow areas would be dark as you visualize them, You can now see why topographical details of a region help you recognize land features as they appear on the radar. Without these details you cannot fully interpret the picture.

Because of beam width distortion, all targets give pips which spread to the left and right of their correct bearing. Thus all targets seem wider than they actually are. A good finite target, for example, will cause a contact 15 degrees or more in width in a typical

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case (SO-1 radar). If two targets have the same range, but differ in bearing by no more than 15 degrees, they will merge into one contact on the scope.

Distortion of the beam width affects radar's portrayal of a coast line. If your beam strikes the coast at right angles, there will be no coast line distortion at that point, but the smaller the angle between the coast line and the radar beam (in horizontal plane, of course), the more the land seems to come out to meet you. This spread tends to reach a maximum at the points of left and right tangency established from the radar observers position. In other words, if you were off a coast line as straight as a ruler, your radar would show it as a slightly crescent-shaped shore line.

bearing is changing fast use CCW off CW switch, as described previously in the section titled "Reading Bearings."

Piloting by radar.

This type of radar navigation may give fixes that are approximate, and fixes that are as accurate as the set itself (plus or minus 2* and plus or minus 500 yards), depending on the features of land. If prominent, finite radar targets, such as peninsulas, river mouths, buoys, large rocks offshore, buildings, lighthouses, and radio towers can be identified on the PPI scope, the best type of radar fix is possible. Under these conditions it is possible to determine set and drift due to current, by comparing dead reckoning with successive radar fixes. Otherwise, the position must be approximated by cutting in on mountain peaks, using left and right land

Since all targets spread considerably in bearing, and incidentally to some extent in range, ships may succeed in concealing themselves from radar by getting as close to shore as possible. Their contacts will then either be obliterated by the land contacts, or they will merge and appear as part of the land mass. Chances of escaping detection will be maximum alongside a high island, and at points of tangency established from the radar observer's probable position.

Special use of SO radar by PT's.

Due to yawing of the PT boat on its course, the relative bearing of all contacts will vary somewhat from one instant to the next. When a torpedo attack is made by full radar control, the accuracy of radar bearings will depend not only on the radar operator, but also on the helmsman's ability to keep the boat on a steady course.

Some PT's draw relative movement lines on the face of their PPI's, and maneuver during the approach so that the target contact comes down one of the lines to one of the range circles. This is done to establish the course of the target without having to plot it, and to reach a definite optimum position for firing torpedoes. *When using a relative movement line on the PPI for target course determination, adjust center control (13) so that the sweep origin is at the center of the PPI*. De-centering the sweep, while useful in getting bearings of nearby objects, introduces distortion, so that the picture is no longer a true plan position view, and ships on a straight course will not move in a straight line on the scope. In the final stage of this approach, the relative bearing of the target may be changing as much as two degrees per revolution of the antenna. When the

tangents, using "range off" lines of position, and by plotting ranges to shore for about every 10 degrees on a transparent overlay, and fitting it to shore-line contours of a chart. These data can be used to good advantage in conjunction with those secured by use of the pelorus and fathometer. If the position must be approximated, it should be estimated by all possible methods and agreements looked for.

Tangents on land are not reliable because of two sources of error. In the first place, beam width distortion makes the land appear wider to the radar; therefore, left tangents tend to be small, and right tangents large. In the second place, radar often ignores low lying or sloping land, so that there may be doubt as to whether the radar is showing the land tangent or some other point inland. This introduces a tendency to carry tangent bearings inland, making the left one too large and the right one too small. These two sources of error offset one another to some extent varying with different types of terrain. Use every opportunity to compare radar tangents with pelorus tangents, so that you know the magnitude and direction of its error on various types of land.

Beware of radar's range off shore, because here again, it may ignore low lying land and indicate that you are farther off shore than you actually are. If the land is precipitous, radar will give your range off shore within the limits of the set's accuracy.

Do not rely on radar to pick up reefs or shoal water. These constitute low lying, poor radar targets, and will be detected at dangerously close range or else not at all.

4-SO-6

SO RADAR

When you are approaching an unfamiliar shore, it is well to study charts and topographical data, and try to predict the way it will appear on the PPI, keeping in mind your approach course. This will facilitate an early radar fix and confusion will he avoided.

When close to shore or entering a harbor, it will be found that land details can often be found by reducing receiver gain (turn gain control 16 counterclockwise). This tends to minimize beam-width distortion and sea-return. Remember, *when studying details of land or entering a harbor, use low gain.*

Jamming.

Jamming is deliberate interference, caused by the enemy, which limits the effectiveness of your radar, or interference produced by our ships to limit the effectiveness of enemy radars. There are several types of jamming, but all are characterized by some form of strong interference pattern in a given sector on the indicator. These interfering signals are directional in nature, and the bearing or bearings from which they come can be easily found by adjusting the cursor to the center of the jamming pattern. The jammer does make it difficult or impossible to read range, but effective jamming is not easy for the enemy to accomplish, and it is apt to disappear momentarily from time to time. Learn to expect it, and he prepared to follow the best course of action when the time comes. Do not mistake interference created aboard your own ship or trouble in the radar set for jamming, the real thing will be directional, and its true bearing will not change immediately when your own ship changes course.

5. Draw a picture of the jamming pattern while it is fresh in your memory, and send it to the Bureau of Ships without delay.

PERFORMANCE

Maximum reliable range.

The maximum reliable range depends mainly upon the antenna height. The higher the antenna, the greater the range of detection of ships, due to the line-of-sight nature of the radiation. The figures given below are for an antenna height of 17 feet. Insufficient data is available at present for performance at higher antenna heights, but comparisons indicate that maximum range performance is roughly comparable to that of the SG radar.

Antenna 17 feet

Target	*Maximum Reliable Range in Miles*
BB, CV, Large auxiliaries	14-16
CA, CL, Medium auxiliaries	10-12
DD, DE, DM, AV, PC, CG, etc.	6-8
Large planes	10-14
Small planes	6-10
Submarines (surfaced)	4-5

Minimum range.

Target	*Minimum Range in Yards*
Ship	300-500
Plane	about 1,000

Range accuracy.

As you approach the jammer, the radar echoes from the jamming ship (if it is sea-borne) will increase in strength more rapidly than the jamming signal, and you stand a good chance of being able to read range through the interference. See Part 3, Defense Against Jamming and Deception.

When jamming occurs:

1. Get the bearing and report it.

2. Keep operating the set and trying to read ranges through the interference. Try various settings of gain control (16). There is a chance the jamming will stop long enough for you to get range.

3. Keep reporting its bearing periodically.

4. Be ready to turn on a radar which operates on a different frequency band if ordered, providing you have one.

The possible errors of the set may add to the probable errors of estimation, so that the following figures result for contacts that are not exactly on a range circle.

Short scale	+/- 500 yards or 1/4 mile
Medium scale	+/- 1/2 mile
Long scale	+/- 1 1/2 mile

Bearing accuracy.

+/- 2 degrees for SO. SO-A, SO-1, SO-2, SO-8 provided your own ship is not yawing on its course.

TROUBLES

Reports from forces afloat indicate operational difficulties caused by moisture getting into the equipment. The transmitter-receiver, and PPI unit of the SO series radars are mounted in watertight cases, and sylica

gel dehydrators (protek plugs) are provided to keep the units dry inside. A few reports have stated that condensation appeared on the scope after the equipment had operated for a few hours, but disappeared after the unit was shut down and allowed to cool. This is an indication that the heat generated by the equipment has driven the moisture out of the dehydrator plugs.

The instruction hook requests that the dehydrator plugs he changed when they have turned from deep blue when dry, to light pink after they have absorbed moisture, and are near saturation. Replacement plugs are sealed at the perforated end to prevent saturation; be sure to remove the seals before inserting in the units.

Abnormally high temperature in the transmitter-receiver unit, due to blower failure or some other cause, will turn off the high voltage automatically. It cannot be turned on again by the usual method. If it is necessary to operate the set in spite of probable damage to it, proceed as described under N E control in the section on Controls.

PART 4

SF RADAR

4-SF-1

RADAR OPERATOR'S MANUAL

SF RADAR

CONTROLS

1. *"A" indicator*: used to identify targets at extreme ranges, for studying composition of echoes, and for accurate ranges.

2. *Range scale*: read the one that is illuminated.

3. *PPI indicator*: used to show tactical situations, for station keeping, and the most watched "scope" during general search. It is surrounded by a relative bearing scale.

4. *Range knob*: moves the range step on the "A" scope, and the range circle on the PPI scope when getting range.

5. *Cal synch*: a semi-permanent adjustment made by the technician.

6. *"A" scope intensity*: controls the brightness of the picture.

7. *"A" scope focus*: controls the clarity or sharpness of definition of the "A" scope picture.

8. *16,000-yard set*: used in calibrating 16,000-yard range, and to put the first range mark on the step; the first range mark represents 2,000 yards.

9. *16,000-yard range set*: used in calibrating the 16,000-yard range, and to put the seventh range mark on the step.

10. *48,000-yard range set*: used in calibrating the 48,000-yard range, and to put the 20th range mark on the step.

11. 4*8,000-yard zero set*: used in calibrating the 48,000-yard range, and to put the first range mark on the step; first range mark represents 2,000 yards.

12. *PPI focus*: controls the clarity or sharpness of definition of the PPI scope picture.

13. *PPI intensity*: controls the brightness of the picture on the PPI indicator.

14. *Calibrate-operate switch*: when in *calibrate* position, range marks appear on the two scopes for

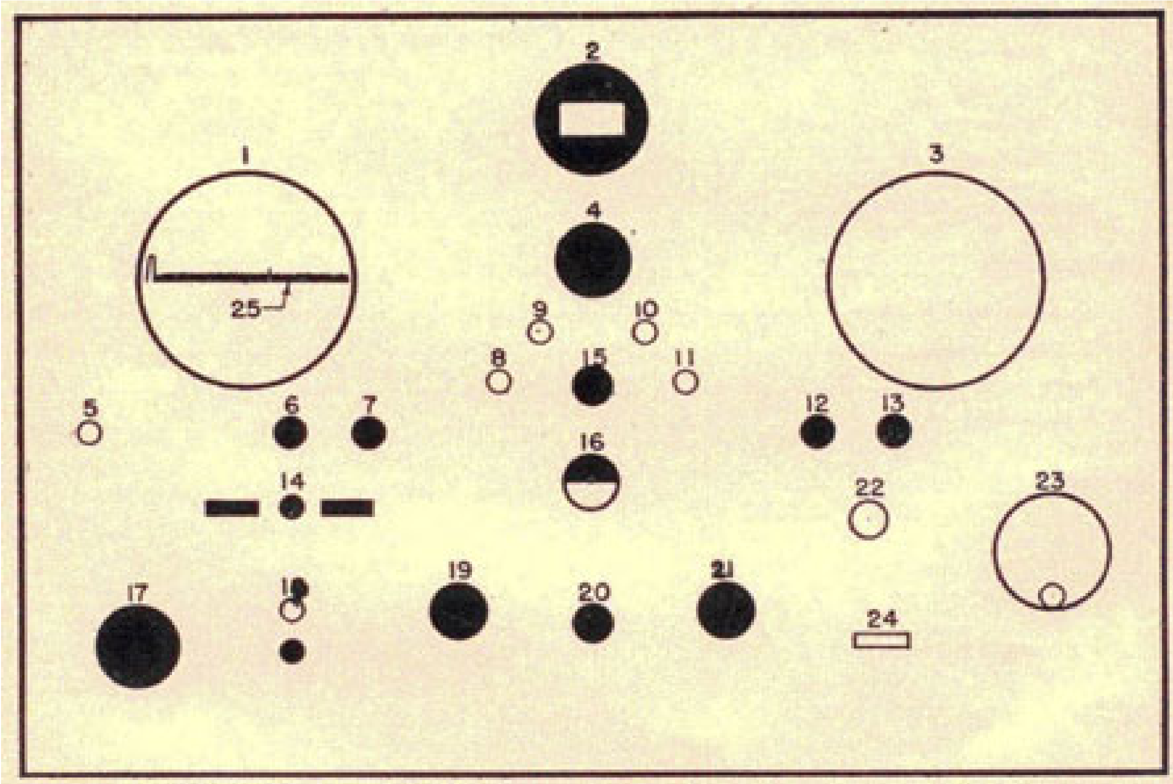

Figure 4 SF-1. Indicator unit.

4-SF-2

SF RADAR

use in calibration. When in operate position, grass and target echoes appear on the two scopes. 15. *Dial light control*: illuminates the PPI bearing scale. This is to be used only when a bearing is being read.

16. *Green tuning eye*: intended to be a tuning aid, but its use is not recommended.

17. *Rec-gain control*: adjusts the sensitivity of the receiver; it controls the height of the echoes and the grass.

18. *Stop-start buttons*: for turning set off and on. 19. *Range switch*: selects either the 16,000-yard or 48,000-yard scale,

TURNING ON AND OFF

Turning on.

Assuming ship's power is on and adjusted to 115 volts DC:

1. Press the black start button (18), on the receiver-indicator. In about 30 seconds, the pilot lamps will illuminate the range scale (2). See that PPI intensity (13) is counterclockwise.

2. Be sure the training control (23) is pushed in for manual operation.

3. After two and one-half to three minutes, the transmitter will automatically go into operation. If you are close to it you can hear the blower motors go on at this time.

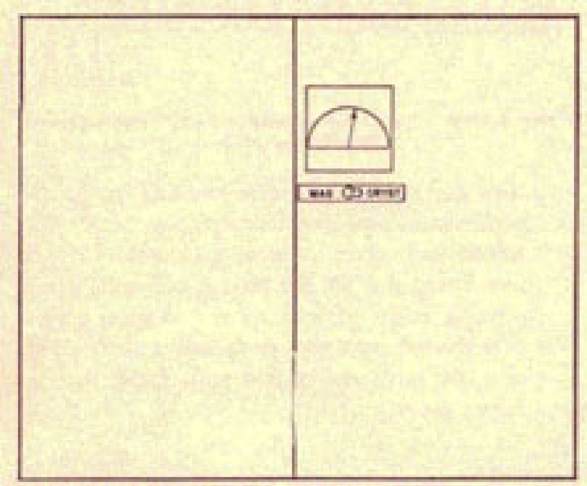

Figure 4 SF-2. Transmitter unit.

20. *Lo-tunning*: this tunes the receiver to the transmitter; it is adjusted to give maximum pip height. This is an extremely critical adjustment, and the one on which the ability of the set to detect targets chiefly depends.

21. *IFF gain*: to be turned clockwise when interrogating with identification equipment. This is inoperative unless BL or its equivalent is used in conjunction with the SF radar.

22. *Warning-training error*: a light which indicates that the antenna (and consequently the target) is not on the indicated bearing. When lighted, it tells us that the antenna training equipment is out of commission and bearings will be wrong until repairs are made.

23. *Antenna train control*: when pushed in, the antenna can be trained by hand; when pulled out, the antenna will rotate automatically.

24. *IFF on-off switch*: when BL or its equivalent is connected to the SF radar, this switch is used to interrogate a desired contact.

4. Look at the meter on the transmitter unit. Set the toggle switch near the meter to MAG and the current should be five to six milliamperes.

5. Set the same toggle on CRYSTAL, and the meter should read between 0.2 and 0.6 milliamperes, if not, the lo-tuning (20) is probably off adjustment. (This is to be discussed later.) Full scale deflection represents 1.0 milliampere.

Turning off.

1. Push the red button marked stop (18 on the receiver-indicator unit).

2. Turn PPI intensity (13) down (counterclockwise).

3. Push in the training control (23) to manual the operation position.

CALIBRATION

16,000-yard scale (at the receiver-indicator unit)

1- Throw calibrate-operate (14) toggle on the receiver-indicator unit to CALIBRATE position.

2. Turn PPI (plan position indicator) intensity control (13) located near the right-hand indicator down to secure PPI during calibration. This prevents burning of its florescent screen during a prolonged period of calibration.

3. Adjust intensity of the "A" scope trace with the "A" scope intensity control (6), located under the left-hand indicator. Do not make it unnecessarily bright.

4. Adjust the focus knob, located under the left-hand indicator, until the "A" scope trace is sharp and clear.

5. Set the 16,000-48,000-yard range selector switch (19), located on the lower left side of the center to the 16,000-yard scale.

6. Set range dial (2), upper center, carefully to 1.75 on the *bottom* scale (1,750 yards).

7. Adjust 16,000-yard zero set (8), located on the lower left side of the range knob, with a screwdriver until the trace looks like figure 4 SF-3. That is, until the first range mark is on the edge of the step as illustrated. The right side of the first range mark, makes an almost straight line from its peak to the bottom of the step.

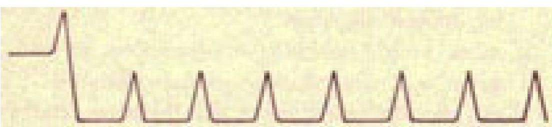

Figure 4 SF-3. Pattern for calibrating 2,000-yard range an 16,000-yard scale.

8. Now set the range dial to read 13.75 on the *lower* scale (13,750 yards).

9. Adjust the 16,000-yard range set (9), with a screw driver, so that the seventh range mark is on the upper edge of the step, as in figure 4 SF-4. Note, that the range marks represent 2,000-yard intervals on the scope. They may be regarded as artificially created pips at ranges of 1,750 yards (first), 3,750 yards (second), etc., the seventh being 13,750. Naturally, you want the seventh one to be on the range step when the range dial reads 13.75.

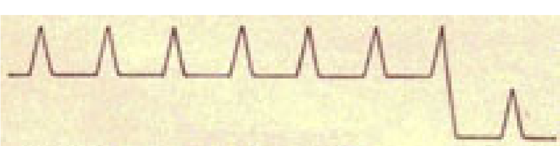

Figure 4 SF-4. Pattern for calibrating 14,000-yard range an 16,000-yard scale.

together. They still represent 2,000-yard intervals.

2. Set the range knob (4) to read 1.75 (1,750 yards) on the *upper* scale (2). Adjust the 48,000-yard zero set (11) to put the first range mark on the edge of the step. See figure 4 SF-5.

3. Set the range dial (2) to read 39.75 (39,750 yards). Adjust the 48,000-yard range set (10) to put the 20th range marks exactly on the step, since the 20th 2.000-yard range mark represents 39,750 yards. See figure 4 SF-6.

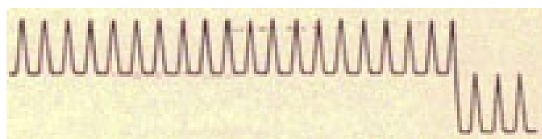

Figure 4 SF-6. Pattern far calibrating 40,000-yard range on 48,000-yard scale.

4. Now alternately repeat steps two and three until adjustments are simultaneously correct. The 48,000-yard range is now calibrated. It has been found that SF and SF-1 radars will have a constant range error of about 250 yards (low) if calibrated on 2,000 yards and 14,000 yards, or 2,000 yards and 40,000 yards rather than as shown above.

OPERATIONAL TECHNIQUE

Receiver-indicator adjustments.

1. Throw the calibrate-operate toggle (14) to OPERATE.

2. Turn up rec-gain (17), located in the lower-left-hand corner, until grass appearing on the sweep (25)

10. Again set the range dial to 1.75 and repeat step seven. Since adjustment of zero set and range set are interdependent, you must alternately repeat step seven and step nine until both adjustments are simultaneously correct.

48,000-yard scale.

Set the 16,000-48,000-yard selector switch (19) to the 48,000-yard range. You now see more range marks than before, since they appear closer

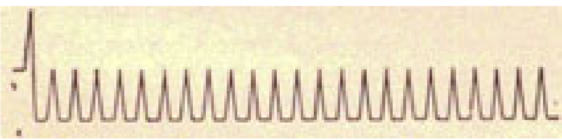

Figure 4 SF-5. Pattern far calibrating 2,000-yard range an 48,000-yard scale.

is about 1/8-to-1/4-inch high. It will look like figure 4 SF-7.

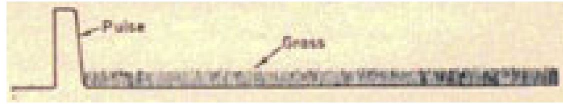

Figure 4 SF-7. Normal grass height.

3. Push in the 10-tuning (20) knob to engage clutch drive and turn it slowly back and forth, at the same time watching for a cluster of pips to rise up at the left end of the sweep. These pips are echoes from waves near the ship, and are known as sea-return (see fig. 4 SF-8). Adjust the lo-tuning (20) until they rise to maximum height. If there are two or more settings

of lo-tuning (20) which make echoes peak up. use the setting which makes them the highest. Do not try to tune by the green tuning eye (16).

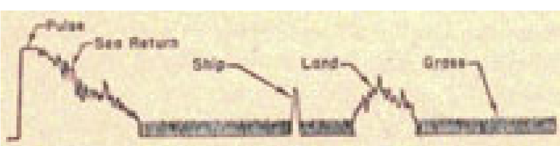

Figure 4 SF-8. Tuning for maximum echo.

4. Targets may be found now by training antenna with the train wheel (23), (located under the right-hand PPI indicator). Train on a ship or land target if possible.

5. Make the final adjustment of lo-tuning (20), by tuning for maximum height of the target pip.

6. Adjust the PPI intensity knob (13), located under the PPI indicator, so that the trace is just visible on the PPI with rec-gain (17) at minimum, turn completely counterclockwise.

magnetic fields always being present, the trace will not line up with the bug (pointer) at all points around the dial. Therefore, bearing readings should always be made from the bug rather than the trace. If true bearings are desired, it will be necessary to install a gyro-repeater near the operator, unless the true bearing modification has been made on your set. Always read bearing in three figures, *zero zero five* instead of 5 degrees. To read bearings in the dark turn tip the dial light intensity knob in the center of the panel.

7. Adjust the focus knob (12), located under the PPI indicator, for a clearly defined sweep.

8. Pull out on the antenna training knob (23), and the antenna will rotate automatically.

9. Adjust the rec-gain (17) for the best picture while watching the PPI. About 4-inch of grass is best if the PPI is to be watched. The PPI is now in operation.

Reading bearings.

As the antenna rotates, a pointer (bug) revolves around the PPI indicator (3) in synchronization with it. The pointer indicates the direction, relative to the ship's head, in which the antenna points. Consequently, it also indicates the relative bearing of the target. New targets cause arc-shaped marks to appear on the PPI (see fig. 4 SF-9). Where they appear depends on their relative bearing and their range. Your own ship is always at the center of the indicator: the farther a target is from you, the more distant it will be from the center of the indicator.

To get the relative bearing of a target, stop the sweep and bug near it by pushing in the antenna training wheel, and then train by hand until the sweep passes through the estimated center of the target echo. It may help to train back and forth on the target until the echo is well defined on the indicator screen, before trying to stop on the center of it. Having done this, read the *relative bearing* on the scale *opposite the bug*. It should be noted, that due to non-uniform

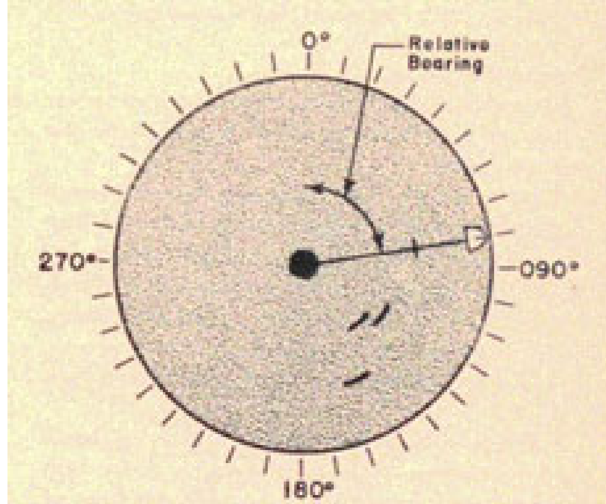

Figure 4 SF-9. Correct bearing setting.

Reading ranges.

The range of an object may be found by ether of two methods; the range circle method, or the step method.

The range circle method is quickest and most commonly used. Notice that a circle of light appears on the PPI. It can be made larger or smaller by turning the range knob. If the circle is made to pass through the target echo, the range of the target may then be read on the illuminated range scale. Notice also, that the upper range scale is illuminated automatically when the 16,000-48,000 switch is on 48,000 yards; the lower range scale is illuminated when on short range (16,000 yards), so there is little chance of reading the wrong scale.

The step method of getting range is more accurate; the "step" can be seen to move back and forth on the "A" type (left-hand) indicator as the range knob is turned. When the target pip is just at the upper edge of the step, as in figure 4 SF-10, the range of the target can be read on the illuminated range scale. Of course, it is necessary to stop the antenna on the target to get the range by this method.

RADAR OPERATOR'S MANUAL

Notice that the range circle on the PPI, and the range step in the "A" scope move in unison and always indicate the same range, which may be read on the illuminated range dial.

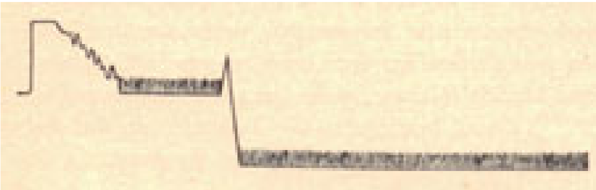

Figure 4 SF-10. Position of step for correct ranging.

Special situations.

The operator should check calibration of both range scales, and the adjustment of the lo-tuning when he comes on watch.

General search. If he is standing a general search watch, the operator will spend most of his time on long range, using PPI and automatic antenna rotation, but making an occasional sweep at 1 rpm on manual control, watching the "A" indicator, Every five minutes it is a wise precaution to switch to 16,000 range scale and search in the sea-return area by reducing rec-gain (17).

Less gain will be required when using the "A" scope than when using the PPI. The gain is carried high when searching for targets at the maximum range of the set, i.e., enough gain to cause a snowy background on the PPI when it is being watched, or about 3/16-inch of grass on the "A" scope when using it. However, it will be turned lower when observing nearby objects.

False contacts. From time to time, false radar contacts will be made. Even with experience it is not always possible to tell with certainty when one has a false contact, so the operator should not fail to report a contact merely because he thinks it is false. These phonies may he caused by invisible ionized clouds, rain squalls, birds, white-caps to evaluator, as the case may be, to give assurance that lie is alert, and that he can be relied upon at night for instance, when the watch officer can see nothing, and the operator is likely to become drowsy. If a report is made to the OOD by way of a bridge talker, the latter should give his report in such a way that the radar operator may listen and sing out if an error is made,

Fire-control. It is conceivable that SF radar may have to he used from time to time for fire-control. When this is done, train on the target, and stop the antenna there; get ranges by the range step method using the "A" indicator. Radar bearings should not be used unless there is no alternative, since the error may be + or - 2 degrees to 3 degrees, It is also possible to pick up the shell, splash and estimate the range error; to spot in range, stop on the target and watch the "A" scope. The shell pip looks like a mouse running under a sheet.

Navigation. Radar is a handy navigational aid when within range of land. It is important, though, to know when you can depend upon it and when you can not. Radar is apt to ignore low-lying land so that any attempt to get the range of a long sloping shore, or the tangent bearing on a section of land that rises gradually, would be unwise. Where land or buildings rise abruptly from the sea, the range to shore or a tangent bearing is easy to get. Mountain peaks and other prominent radar targets, are often identified by reducing rec-gain, since they will be the last targets seen as the gain is cut down. All targets on the PPI appear wider than they really are, due to the width of the beam of energy from the antenna. For this reason, tangent bearings may have to be taken inland a few degrees, the exact amount depending on the strength of the echo. Experience will improve this technique.

Since ranges are relatively accurate, range fixes on two positively identified, small, finite targets, are dependable.

windward, small floating objects, and less common items. For further information, see the section on Pipology, Part 3.

Reporting. The operator should keep careful track of all visible contacts and watch especially for the sudden appearance or disappearance of echoes (strong indications of subs). He should also report all ships when they first become visible, report ships which may pass dangerously close, watch for ships on collision course (those whose bearing remains constant as the range closes), and make a routine report on first picking up land or losing it. Furthermore, it is a good policy to have the operator make some sort of routine report every five or ten minutes to the OOD, or

When entering waters in which the PH picture is complicated by many strong land echoes (as in a harbor), it is necessary to reduce rec-gain to see the land-sea boundary, because of the blurring effect of the beam width distortion, and the obliterating effect of sea-return at close range.

Jamming and deception.

There is no doubt that the enemy considers our radar an extremely dangerous weapon, and consequently it is only reasonable to expect him to try every means possible to make it less effective. He may use two tactics to do this: jamming and/or deception. Every

---

operator should learn how to recognize these countermeasures, and to expect them when in combat zones.

When the enemy broadcasts radio signals, intending that our radar receive them, and they show a confusing pattern on the screen, it is called *jamming*. Use of dummy targets (tinfoil, kites, balloons, etc.) is called *deception*. Of course, more precise definitions are sometimes given, but these are satisfactory for this discussion.

The SF radar can he jammed, and it will show echoes from the tinfoil the enemy sometimes throws out to confuse the operator. The operator should no! become alarmed when either of these things happens.

If you were suddenly confronted with jamming, without previous experience, it would appear impossible to work through. However, it is not really that serious if the following procedure is carried out:

The two general methods of using the gain control are:

> a. Reduce the setting; this prevents overload of the radar receiver; echoes are visible "riding on top" of the jamming pattern.
>
> b. Increase the setting; this limits (or clips) jamming; echoes are visible as a break in the base line. Be sure to return the gain control to its normal setting when no jamming is present, or when the antenna is turned to an unjammed bearing. Both of these methods should be tried.

Try changing the receiver local oscillator tuning. When you change the lo-tuning, you lose some of the height of the desired echo. However, if the jammer is not exactly on your radar frequency, there is a chance that you will detune the jamming signal more than the echo signal. Considerable improvement can sometimes be obtained this way. Try swinging the lo-tuning dial in both directions to

1. DF on the jamming.

2. Use available anti-jamming devices on the receiver when provided.

3. Try moving the gain control up and down.

4. Try changing the receiver local oscillator tuning.

5. Keep operating.

6. Report type and bearing of the jamming to CIC.

The first reason for obtaining a bearing on the jamming is to determine whether or not it could be accidental interference instead. Jamming will not only be directional, but its true bearing will not be changed by any sudden change in your ship's course. Interference originating aboard your own ship will either he non-directional and appear on all bearings, or else it will always be on some certain relative bearing regardless of your own ship's course.

Try moving the gain control up and down. This is probably one of the most important countermeasures than can be taken, and the one most commonly overlooked because of its simplicity.

In most cases, except when effective noise modulated jamming is being encountered, there is a setting of the gain control where it is possible to range on a target in the presence of heavy jamming. If there are several echoes on the same bearing, the best setting for each echo is different. Of course, it is more difficult to obtain these ranges because of the distortion of the echo produced by jamming, but it is possible to obtain see which direction makes the greatest improvement. Note the correct setting of the lo-dial, so that it can be returned to its normal position when no jamming is present, or if detuning does not help, otherwise the radar will not give optimum performance.

Even if the jamming is extremely effective, keep operating and do not turn your radar off. Turning your radar off informs the enemy that his jamming is effective, and certainly makes the radar completely worthless. The effectiveness of the jamming may change from time to time, so if you are persistent enough some information may be obtainable.

Report the nature and bearing of the jamming to CIC. Recognizing the type may be difficult because non-synchronous patterns sometimes appear blurred beyond recognition. Inasmuch as knowledge of jamming type* may possibly help identify the jammer in some cases, this information should be reported if possible. *Above all, never turn off the radar*.

When jamming and/or deception is encountered, full 360 degree search must be continued. However, the antenna should be stopped from time to time for short intervals, in order to try reading through the jamming, using the "A" scope. You also must be prepared for any diversionary tactics, for the enemy may or may not use jamming and 'or deception to divert your attention from the bearing of the main attacking forces. This problem is simplified somewhat when similar but separate radars are used for reading through jamming and for searching.

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* See part 3, Defense Against Jamming and Deception.

the desired information. However, the extra effort is worth while, because the enemy would not he jamming unless he were trying to conceal something important.

4-SF-7

RADAR OPERATOR'S MANUAL

PERFORMANCE

Maximum reliable range.

The maximum reliable range on various types of targets depends on the height of the antenna. The higher it is, the greater will be the maximum range of detection. This is especially true for large ship targets. The performance data below shows approximately what you can expect if your antenna is between 50 and 70 feet above the sea.

Type of Target	*Approximate Maximum Reliable Range in Yards*
BB, CV, Large auxiliary	33,000
CA, CL, Medium auxiliary	28,000
DD, DM, AV, PC, CG, etc.	19,600
Submarines surfaced	9,000-15,000
Submarine periscopes	2,700
Buoys	7,000
PBM, PMY, PB2Y at 1,000 to 3,000 feet altitude	27,500
SOC, OS2U, SBD, F4F, F6F, etc., at 1,000 to 3,000 feet altitude	14,000

Minimum range.

The minimum range with all controls adjusted for shortest range detection will vary somewhat, depending on the roughness of the sea. A rough sea, means more sea-return interference and

Range accuracy.

The range accuracy of this radar will be best when the ranges are read from the "A" scope using the step. The accuracy under these conditions is about +/- 200 yards, + 1.0% of the range. In other words, even when you calibrate correctly and read the range indicated by the range dial properly, your radar range may be off 400 yards on a target 20,000 yards away, or 600 yards on one 40,000 yards away, but only 220 yards on one 2,000 yards away.

Bearing accuracy.

Bearing accuracy will he best when the contact is strong and steady. By using manual antenna train, that is, stopping the sweep in the center of the contact seen on the PPI, a good operator will usually be within +/- 2 degrees of the correct bearing of such a target. If the contact is E-1*, and visible only periodically the error may rise to 3 degrees or 4 degrees.

TROUBLES

If for any reason the bug should fail to give the correct relative bearing of the antenna, the light near the train wheel, marked warning training error, will glow. The technician should be called if this light continues to glow, but an occasional intermittent flash will be of no consequence.

Gunfire or depth charging might possibly jar open relay K 201, which is located behind the front panel of the transmitter unit. If this happens, the

greater minimum range, especially on smaller targets. The figures below show approximately what to expect:

Minimum range.

The minimum range with all controls adjusted for shortest range detection will vary somewhat, depending on the roughness of the sea. A rough sea, means more sea-return interference and greater minimum range, especially on smaller targets. The figures below show approximately what to expect:

Type of Target	*Minimum Range in Yards*
Ship	600
Planes	1,000 to 1,600

transmitter will become inoperative for about 2 minutes, but will come on of its own accord at the end of that time.

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* See Part 1, How Does Radar Determine Bearing-E Units.

4-SF-8

Part 4

SJ-a, SJ-1 RADAR

RADAR OPERATOR'S MANUAL

SJ-a, SJ-1 RADAR

CONTROLS

Main control unit.

1. *Main off and on switch*: applies AC voltage to the SJ radar set.

2. *Green light*: when illuminated this indicates the main switch is on.

3. *Load voltage meter*: indicates the voltage applied to the radar set.

4. *Load autotransformer*: controls the voltage reading of 3.

5. *Regulated rectifier voltage meter*: indicates the DC voltage output of the regulated rectifiers.

6. *Meter switch*: positions 1 and 2, determines which regulated rectifier voltage is indicated on 5.

7. *High voltage rectifier off-on switch*.

8. *Red light*: indicates when the AC power is applied to the high voltage variac.

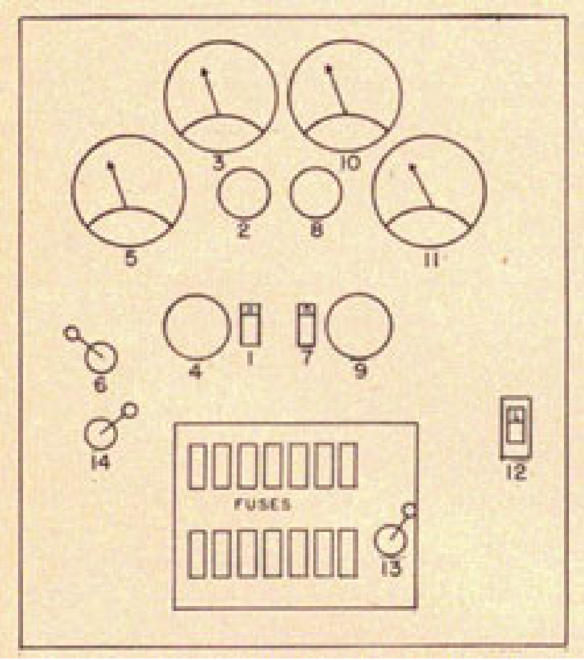

Figure 4 SJ-1. Main control unit.

12. *Antenna control on-off switch*: controls the applied to the automatic training device.

13. *Heater switch on-off*: controls the AC plied to the heating elements in the range and transmitter-receiver unit.

14. *Pilot lights*: bright-dim switch.

Transmitter-receiver unit.

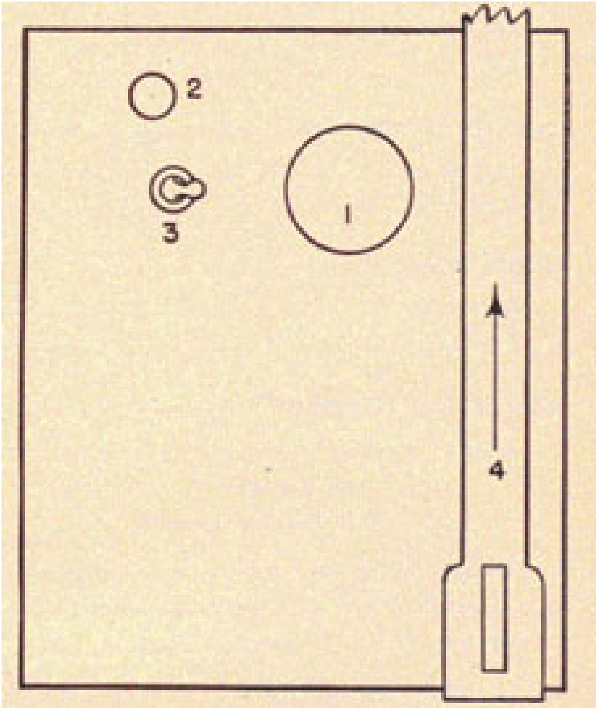

Figure 4 SJ-2. Transmitter-receiver unit.

1. *Crystal current meter*: reads 0.5 to 0.7 milliamperes when the equipment is properly tuned (this, however, is not the maximum crystal current reading obtainable).

2. *Fine pulse rate control*: will vary the pulse repetition rate from 1,300 to 1,700 pulses per second.

3. *A.F.C. on-off switch*: the automatic frequency control (automatic tuning circuit) will tune the receiver when ON, however, this circuit drifts and should be used only to *check* manual tuning.

9. *High voltage variac*: controls the DC output of the high voltage rectifier.

10. *High voltage rectifier voltmeter*: indicates the DC voltage applied to the transmitter-receiver unit.

11. *High voltage rectifier current meter*: indicates the current in the rectifier circuit.

4. *Wave-guide transmission line to antenna*.

Range-indicator unit.

1. *Horizontal centering control*: controls the position of the sweep or picture on the scope.

---

2. *Lobe separation on-off*: allows separation of pip, on the scope for lobe switching.

3. *Lobe separation*: determines the amount of separation of the pips when 2 is on.

4. *Sweep control*: determines the length of sweep on the scope.
(a) Main sweep: 0 to 60,000 yards.
(b) Expanded sweep: 0 to 20,000 yards.
(c) Precision sweep: 3,000 yards (1,500 yards each side of the range step).

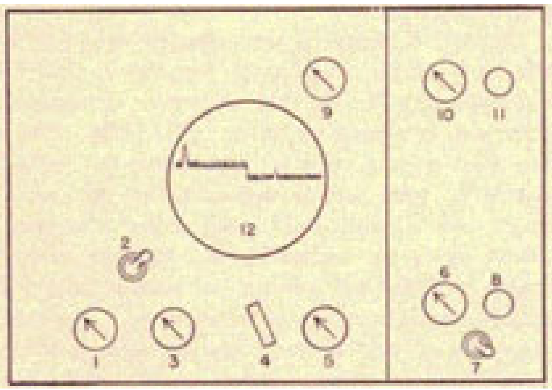

Figure 4 SJ-3. Range-indicator unit.

5. *IF gain*: controls output of the receiver (determines height of grass and pips).

6. *Focus control*.

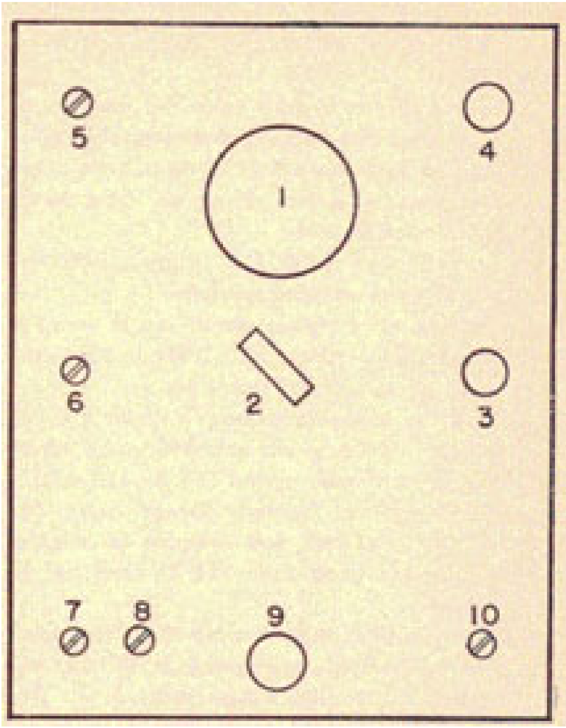

Figure 4 SJ-4. PPI unit.

Range unit.

1. *Dial light dimming switch*.

2. *Heating circuit indicator lamp*.

3. *Range counter dial*.

4. *Zero adjustment*: to be adjusted by the technician.

7. *Lobe motor on-off switch*: applies power to the lobing motor.

8. *Intensity control*: screwdriver adjustment, to be set by the technician.

9. *Range zero knob*: used to zero the sweep.

10. *Receiver-tuning*: tunes the receiver to the transmitter frequency.

11. *Noise suppression*: screwdriver adjustment, to be set by the technician.

12. *Scope*: cathode-ray tube.

PPI-indicator unit.

1. *PPI cathode-ray tube*.

2. *Sweep selector switch*: (8,000, 40,000, 80,000 yards range).

3. *Scale light*: azimuth circle.

4. *Driving cable*.

5. *Video gain*: screwdriver adjustment.

6. *Focus*: screwdriver adjustment.

7. *Horizontal centering*: screwdriver adjustment.

8. *Vertical centering*: screwdriver adjustment.

9. *Range circle*: adjusts intensity of the range dot.

10. *Intensity*: adjusts brilliance of the scope.

5. *Counter adjustment*: to he adjusted by the technician.

6. *Clutch adjustment*: to be adjusted by the technician.

7. *Range crank*.

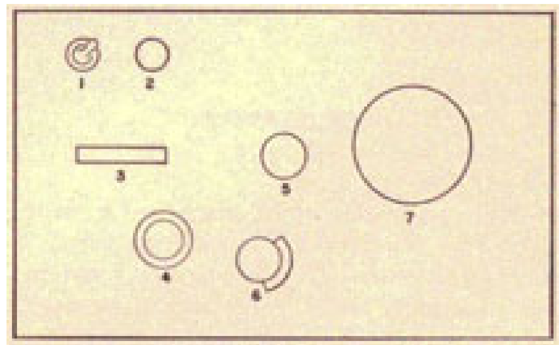

Figure 4 SJ-5. Range unit.

RADAR OPERATOR'S MANUAL

TURNING ON AND OFF

Turning on.

Open antenna wave guide valve and perform the following operations from the main control unit:

1. Turn on heater switch (13) 30 minutes before attempting to operate, if at sea, leave heater switch on at all times.

2. Turn on main switch (1), a green light will glow if set is operating correctly.

3. Check to see if blower motors can be heard in the transmitter-receiver unit, If not, turn the main switch off and call the technician.

4. Check the load voltage meter (3) for 120 volt reading. If this is not indicated, make adjustment of load variac control (4) for 120 volts.

5. Check regulated rectifier voltage meter (5) for 300 volts, check both positions of switch 6. If either one is off more than 15 volts, call the technician.

6. Turn on high voltage switch (7) 55 seconds after line switch was operated, a red lamp will light (8) if the high voltage switch is on. The high voltage should immediately jump to 0.9 and to 1.2 K.V.; providing the H.V. variac has been left at its proper setting when set was last secured.

7. The high voltage rectifier current meter (11) should read between 140 and 160 milliamperes.

8. Check the load voltage meter (3) again, for a value of 120 volts.

9. Turn on antenna control switch (12).

the paper and because the scale of the chart is too small. The range of a reference target, to be used for calibrating purposes, should be known within 5 yards.

Where such a known range is not available, all SJ-1 equipment should use the counter setting of 99,940 for zero set. This number has been established by repeated observations over accurately surveyed ranges, and while it is subject to a possibly 10 yards variation among equipment, it should be used in preference to any but positively known local reference ranges.

One way of accurately determining a range, is by the use of double range echoes, (see Part 1, *External Calibration*). To do this, maneuver alongside a large ship at a range of 500 to 1,500 yards. When you train your antenna on this ship, two echoes should be seen; one at approximately the correct range, and a small double-range echo at approximately twice the correct range. Read these two ranges carefully and subtract the smaller from the larger-the difference is the actual range of the ship, regardless of whether your radar has been properly zeroed or not. Assuming this range is 800 yards, to find the exact zero set figure for your radar, you would proceed as follows: crank the range counter to exactly 800 yards and use the zero adj. knob to line up the target pip and step (use precision sweep during this operation). Now crank the range knob until the left edge of the transmitted pulse lines up with the step, and then read the range counter. It will probably read somewhere between 99,940 and 99,960 yards. Record the reading for future use in making the zero set adjustment. It is wise to avail yourself of every opportunity to check the zero set by means of double range echoes. If the double range echo appears at exactly twice the range of the true echo, you can be sure that the zero set

Turning off.

1. Turn off antenna control switch (12).

2. Turn off high voltage switch (7), *do not* reduce high voltage variac (9).

3. Turn off load voltage switch (1).

4. Do not turn off the heater switch (13) unless the set is to be worked on. Other units need not be touched.

CALIBRATION

Zero setting.

There has existed sonic uncertainty as to the proper *zero set* adjustment. In most cases there is no reference target available, whose range is known precisely enough to enable a satisfactory determination of zero set correction. Scribing ranges from charts is not generally satisfactory, because of shrinkage of adjustment is correct.

Under no circumstances should zero set be made with the counter at 00,000. This would increase all range readings by about 60 yards, and would go far toward defeating one of the main contributions of radar-accurate ranges.

The correction is required due to two factors: distance traveled from the transmitter to and from the antenna, and certain transmission delay and other effects within the equipment, such as build-up time in interstage filters.

Zero set procedure.

Torn on the set and tune properly.

---

2. At range unit, turn range crank counter-clockwise until range dials read exactly 99,940 yards, or a more accurately determined figure found by double range echoes.

3. Turn IF gain fully clockwise (5 on range indicator unit).

4. Set sweep selector switch on precision sweep (4 on range indicator unit).

5. By adjusting the set range zero knob, move the step to the right until the leading edge of the transmitter pulse meets the downward portion of false echo on the scope. The receiver can he reliably tuned on such an echo, as soon as the antenna is above the water.

7. If targets are available, train on one, and turn on the AFC switch on the transmitter (3). If the automatic tuning circuit is working properly, and if manual tuning is correct, no change in echo height should occur. In any case, if echo height increases, the manual tuning is not correct.

Note: The AFC circuit should be used only to check manual tuning.

the step, as shown in figure 4 SJ-6.

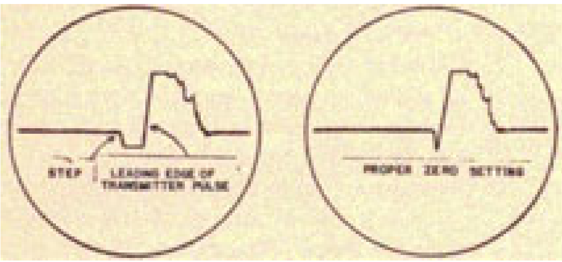

Figure 4 SJ-6. Transmitter pulse for proper zero set.

OPERATIONAL TECHNIQUES

Tuning the receiver (at range-indicator unit).

1. Check sweep switch (4) on all three positions to see if a sweep and step are present on the scope for each position. If any are missing, notify the technician.

2. Turn IF gain (5) fully counterclockwise; and adjust focus (6) for narrowest sweep or line possible.

3. With sweep switch (4) on expanded, rotate IF gain fully clockwise.

4. Adjust receiver tuning control (10) for maximum pip height on scope if pip is present. AFC switch (3) on transmitter-receiver unit must be off during this adjustment.

5. If pip height is saturated (pip has a flat top and not a sharp point), reduce IF gain (5) until pip is pointed, and make further adjustment of receiver tuning control (10) for maximum pip height.

6. Should no echo be present for use in tuning, put the sweep switch (4) on precision and the range dial at about zero. Tune for maximum indication of the wave echoes. If no wave echoes or other indications are available, the experienced operator can tune the set by noting: appearance of

8. Adjust wave guide valve for maximum tuning or echo height.

9. Never use receiver tuning control (10) to decrease pip height. Always use IF gain control (5).

Adjusting PPI intensity. It is to be noted, that this control must he set precisely, and not varied to suit personal preferences and lighting conditions. Adjust *intensity* (10 PPI unit) until the sweep trace is just visible on the scope, when the IF gain (5 on range indicator) is set at minimum.

Any light which shows, with no signals or noise present, will impair the usefulness of the indicator by reducing the contrast of the pattern, that is, echoes will not stand out clearly nor be distinguishable from noise.

The intensity should not be turned too low, because then, unless special care is taken, weak signals will not be able to excite the screen sufficiently to be detectable.

Drift in tuning during warm-up. When the system is turned on, after a considerable period of shut-down, at least 5 to 10 minutes is required for the beat-oscillator in the receiver to reach final, stable, operating temperature. This period can be reduced to about two minutes by applying line voltage to the SJ-1 at least 10 minutes before surfacing, and by opening the antenna wave-guide valve. High voltage maybe applied before the antenna breaks surface and tuning checked approximately, by the appearance of the transmitted pulse on the precision sweep, with the range crank at about 99,940 yards. Zero setting of the range step is also checked at this time. Use hand train of the antenna, and report to the Captain when the antenna is free of water. Immediately check tuning on sea-return (wave pips), and make two complete 360 degree searches, reporting the results of each search. These searches should he made on expanded sweep. Continue to search with

transmitter pulse on precision sweep, and reading of the crystal current meter on the transmitter unit. If an echo box is available, it can he used to put a hand train of the antenna until surfacing is complete.

Reading bearing and range.

1. To obtain approximate bearing of the target, rotate the antenna crank back and forth (lobing

off), until maximum height of the pip is found. Read the bearing on the bearing indicator and subtract 2 1/2 degrees from this reading. The result will be an approximate or *non-lobing* bearing.

2. When an accurate bearing of the target is desired:

(a) Turn the lobe motor switch (7) on the range indicator unit on.

(b) Turn on the lobe separation knob (2) on the range indicator.

(c) Rotate lobe separation knob (3) clockwise, until two pips and two steps are present, as illustrated in figure 4 SJ-7.

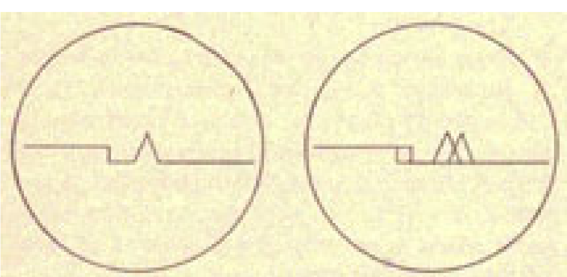

Figure 4 SJ-7. Scope with and without lobing.

(d) Rotate antenna crank back and forth until the two echoes are at the same height.

(e) Read bearing dial for correct bearing of the target with respect to own ship-*relative bearing*. touched. Minimum time will then he required for obtaining lobe bearings.

Due to increased power output of SJ-a and SJ-1 radars, minor lobes present considerable trouble at close ranges; they can be easily located and avoided by use of the PPI scope. Echoes from minor lobes (side lobes) will disappear as receiver gain is decreased.

Bearings and ranges may he read approximately from the PPI scope without stopping the antenna. It is possible to obtain target course within 5 degrees, and target speed within 3 knots from this data. The following suggestions will speed the obtaining of data from the PPI and increase the accuracy:

> 1. Add inked circles on the face of the PH tube for estimating range (four solid circles, interspaced by four dotted circles). Care must he taken not to scratch the tube in any way.
>
> 2. Improvise a more accurate 360 degrees bearing circle over which rides a cursor, or thread stretched across the screen. Targets may then he split by this thread and hearing read on the circle.

Operation at short range.

Any radar antenna projects a small amount of energy in every direction. This can be visualized by

3. To measure the range, first turn lobing switch (7) off; then rotate the range crank, which moves the step on the scope, until the step is approximately at the pip being measured.

4. Turn sweep switch to precision sweep.

5. Advance the step until the beginning of the pip sets exactly in the corner of the step as in figure 4 SJ-8.

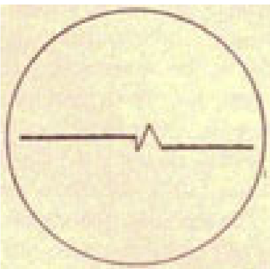

Figure 4 SJ-8. Position for correct ranging.

6. When the pip is in the step correctly, the range of the target can be read from the range dial on the range unit.

It is suggested, that after adjusting *trace separation* correctly, that the lobe separation switch be left on at all times, and that the trace separation knob not be

comparison with a searchlight. There is a certain amount of illumination, even directly behind the light. In the case of SJ-1, the distribution is known, and is such that a very small amount is projected to the rear of the antenna. This is obviously extremely low, but since the sensitivity of the receiver is such that a signal will begin to show when the received energy is infinitesimally weak, it is not surprising that when the IF gain is set high, an echo will be received in practically a full circle, from a large target, at ranges of less than 2,000 yards. The only recourse in such a ease is to reduce the IF gain sufficiently to remove all but the main echo.

In a situation where this is done, it is well to use the time between taking data to turn up the gain, and to observe any other targets which may not be seen with the low gain setting required to resolve the short-range contact. *It is stressed, that the IF gain must continually be adjusted to suit circumstances during any operation, except long-range search.*

It will be found, that as range is closed, the arc subtended by an echo will increase. This is particularly evident on the PPI. There are two reasons for this: the angle subtended by the target will increase; and the echo will begin to show well before the antenna bears full on the target. Reducing the IF gain will

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SJ-a, SJ-1 RADAR

make the latter effect negligible, but at the same time reduce long range sensitivity.

The following search routine is suggested for SJ-a and SJ-1 equipment: 360 degrees searches are to be made at all times; suggested antenna speeds are 6 rpm, or less, for PPI search, and 1/2 rpm for "A" scope search.

1. Use the PPI 80,000-yard scale (high gain) for 2 minutes.

2. Use the PPI 40,000-yard scale (high gain) for 5 minutes.

3. Use the PPI 8,000-yard sweep (low gain) for 2 minutes. (or "A" scope expanded sweep in hand train).

High gain indicates the most efficient receiver gain setting for long-range search. *Low gain* refers to the receiver gain sufficiently reduced to enable targets to be detected inside the sea-return area. Care must be taken not to reduce gain too much. It has been found that alternate PPI and A scope searching provides diversion for operators, thus relieving strain.

The following suggestions pertain to the tracking of targets:

It suggested that operation of the SJ-a underway, be carried on with half-hour watches, if possible. In no ease, should the watches be for more than one hour. Radar watches may be combined with sound, radio, or both, but should under no circumstance be combined with lookout watches. When relieving the watch, all meters should be checked for proper readings, and the three indicator sweeps checked for proper operation. Tuning and zero-set should be checked, and special information, such as maximum range on wave pips, interference present, etc., should be obtained from the operator. Any indication of trouble should be reported to the radar technician or radar officer. In case trouble occurs in the set during the watch, immediately turn off the high voltage in the transmitter' and secure the set, reporting the sequence of events which occurred when operation failed. Location of trouble may be greatly speeded in this way.

Pipology.

Clouds and rain squalls. These can frequently be detected at great ranges, and are not always easily identified. Usually, they will show on the PPI as being several degrees wider than normal ship echoes, depending on the extent of the cloud. They will frequently tend to look like landfalls, but can be distinguished from such, where certainty as to ship's location is lacking, by tracking to determine whether the target has course and speed as clouds have when driven by wind. Fluctuation of the echo is not necessarily an identification, because at long ranges land echoes sometimes fluctuate abnormally. Echoes from clouds are usually mushy, due to the absence of definite, reflecting planes.

Birds. Echoes from birds constitute a source of confusion to radar personnel. Birds in flight can usually be identified by their random courses and speeds, as well as by the fact, that, being so small, they will only show echoes at ranges within 2,000 yards. There should be no confusion between birds

1. Designate multiple targets on the PPI as Able, Baker, Charlie, etc.; escorts as escort one, escort two, etc.

2. Have the plotting officer look at the disposition of the targets on the PPI when approach begins. He may assign designations.

3. Keep the antenna in hand training while obtaining bearings for TDC.

4. Obtain data for the TDC by use of the "A" scope only.

5. Use a second operator to aid in reading "A" scope data, and ranges on escorts and secondary targets.

If necessary, shift the antenna to power training for a 30-second interval every two or three minutes, to secure this auxiliary data. Complete search must be made at least every three minutes.

6. The best estimates possible of target size and type must be passed to the plotting officer and to TDC, as well as apparent changes in the course of target. These generally become widest due to changes in the echo strength on the PPI and "A" scope.

If provisions are not available for operation of IFF with SJ-a or SJ-1 radar, all questionable targets should be challenged by means of the SD radar's IFF system. Simply look for IFF response at the range of the surface target on the SD screen. See Part 2. General IFF Principles.

and aircraft, because the latter will show stronger echoes and will be seen at far greater ranges than the birds.

Ships. The approximate size of ships can be estimated by the maximum range of detection, the rapidity of the bobing motion, and in some cases the speed. The first two factors will be affected by the following:

(a) Target size.
(b) Sea condition.

(c) Target type (amount of freeboard, lines, superstructures, etc.)
(d) Target course (presentment).
(e) Target speed (variation of reflecting surfaces).
(f) Own speed (variation of our antenna pattern).

Aircraft. The beam of the SJ-1 antenna, is directed toward the horizon, but low flying aircraft will frequently produce echoes. To recognize them, set the range mark on the echo, and watch for noticeably fast target motion. The PPI can also be used. The course of the aircraft might be such that range changes slowly, in which case, the PPI will indicate rapid change of bearing. It is important to realize, that echoes from aircraft will never zip across the screen, because so much range is compressed and displayed in the few inches of the screen. Even projectiles can be followed with ease. An airplane traveling at 200 mph, either directly toward, or away from the antenna, will require about 40 seconds to traverse the prec. sweep.

Minor lobes. It is characteristic of radar antennas, that some energy is projected in minor lobes or beams of energy, at some divergence from the main beam. In the case of SJ-1, the required small size of the antenna, as well as the necessarily massive construction of the projector head, accentuate the minor lobes. These are greatly reduced in power from the main lobe, but echoes will be received in response to minor lobes when the target is large, close, ad the IF gain is high. When present, minor lobe echoes will show at roughly 15 degrees divergence from the main echo, and at the same range as the main echo.

The presence of minor lobe echoes is easily observed on the PH. Since they are weak, compared to the main echo, they will not show on small or distant targets. Roughly, with the IF gain

Where uncertainty exists, as to whether a particular signal is real or a minor lobe echo, positive check can be made by attempting to lobe-switch on the echo in question. It will be found, that the two pips from a minor lobe echo will tend to rise and fall together, instead of sea-sawing, as a main echo does when the antenna is trained through the bearing of the target.

Jamming.

Since local interference or trouble may resemble jamming, an operator, after first reporting it, should perform these cheeks to see if the signals are from an outside source. Check whether the strength of interference varies as the antenna bearing is changed; or whether interference disappears when the antenna wave-guide valve is closed.

If interference is external and from another radar, it will consist of a definite series of equally strong pulses, consistent in width and spacing. These pips may move to the right or left on the screen (pulse spacing remaining constant), depending upon the pulse repetition rate of your radar and that of the interferer. Their speed of travel along the time base may be varied as your own pulse rate is varied. The interference will disappear when the wave-guide valve is closed. They are definitely effected by a variation of receiver tuning, and vary in strength as the antenna is rotated.

Note: All of the above points will appear on the PPI scope as bright spots, moving along the sweep (or as spirals from the center to the outer edge, if the antenna is rotating).

If the interference is external, and from an intentional jammer, it will generally conform to a known type of jamming signal, and may not be effective enough to prevent an operator from seeing targets in the jammed sector. It will also disappear when the wave-guide valve is closed. It will

well up, minor lobe echoes may be expected from a destroyer at 3,000 to 6,000 yards. The nominal divergence of 15 degrees will vary among installations, and the minor lobes will seldom be alike in strength.

Where a group of targets, such as a convoy, is being viewed, echoes from minor lobes are confusing. The first recourse is to study the PPI pattern, for main and side echoes in characteristic groups, and to reduce the IF gain to where only the main echo from each group remains. Where the range is short, and the convoy is widely spread, this must be done judiciously in order not to lose real echoes from small targets, such as wooden escort vessels.

definitely vary as antenna bearing is changed, and due to the strength of the signal, it may burn a definite, brilliant sector on the PPI scope.

To read through jamming, concentrate on the "A" scope in the jammed sector; an experienced operator can spot a target on it most of the time. Do not neglect searching completely around 360 degrees. The effectiveness of a jammer, which is covering a target you are tracking, may be decreased by very slightly changing receiver tuning without losing your echo. Training the antenna slightly off the target, to one side or the other, may reduce the jamming more than the echo. Changing pulse repetition rate, or changing the high

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voltage applied to the transmitter, and retuning the receiver may help.

A jammer must continually transmit at the radar frequency of your radar. You can slightly vary the frequency by varying high voltage, as described above. The corresponding correction on the part of the jammer, may allow a free operating interval.

Do not give up trying to read through a jamming signal, because as the range of a jammer closes (and the range of any accompanying target), the target echo will increase much faster in strength than the jamming signal. The higher the frequency of transmission, the harder the job of jamming, hence, the easier the task of evading or reading through. Enemy use of radar jamming in the Pacific has not been pronounced, but can be expected as soon as they can produce equipment which will do the job.

Mechanical jamming.

4. Size and height of the target, also, material of the target.

5. Atmospheric conditions.

Of these, the first three are entirely obvious. Concerning item (4), a slight degree of confusion is possible when attempting to judge the size of a target by the strength of an echo, because a large wooden ship will usually not produce an echo larger than a considerably smaller steel ship.

The effects of atmospheric conditions are comparatively obscure, but a few generalizations may be made. Fog causes occasional slight reduction in range. Heavy rain causes some reduction, but no cases are known of serious reduction due to rain. It seems well established, that in the North Temperate zone there is some daily cycle, whereby range capability of SJ-1 radar equipment, increases above normal in the late afternoon and early evening.

The Japs and the Germans have been known to use several types of radar deception. *Window* has been used in an attempt to hide aircraft. It consists of concentrations of reflecting material, which can be spread by dropping it from aircraft, or by firing it from a gun. It may also be used to *mask* ships. This material presents a numerous collection of pips, which may cover a wide sector; all pips fluctuate at a very rapid speed, and may appear quite similar to a cloud, though much stronger.

Echoes emanating from balloon bourne reflectors have been used to draw radars off of true targets. If you track these, their course will he that of the wind and one-half to two-thirds of the wind speed.

Diving procedure.

When the word "*standby to dive*" is passed, remove high voltage from the transmitter, and close the antenna wave-guide valve. Secure the rest of the set in a routine manner. The antenna should be secured on a 180 degrees bearing when not in use, especially while running on the surface.

PERFORMANCE

Maximum reliable range.

The range capability of a given installation is effected mainly by the following conditions:

1. General condition of the radar.

2. Accuracy of the tuning, particularly the rec-tuning control.

3. Height of the antenna above the water.

Antenna 33 Feet

Target	*Maximum Reliable Range in Yards*
BB, CV, Large auxiliaries	25,000 to 30,000
CA, CL, Medium auxiliaries	20,000 to 25,000
DD, DE, DM, AV, PC, CG, etc.	15,000 to 18,000

Mountainous landfalls and freak conditions, can produce echoes under conditions which may lead to considerable confusion, if not fully understood. The maximum range displayed on the indicators is nominally 80,000 yards (PPI). However, echoes have been received many times from ranges so great, that the received echo does not arrive until the next succeeding *sweep*, or cycle of operation. Such *second-sweep echoes*, usually appear on the indicators at relatively short ranges, and can he misinterpreted as nearby targets. In the SJ-1, provided with variable pulse (recurrence) rate control, this type of false signal can quickly be identified by shifting the pulse rate control on the transmitter back and forth. This will cause any *second-sweep echoes* to move back and forth in range across the screen. Since this condition cannot be called rare, remember, the best protection against it is to understand the possibility, and the method of checking.

Minimum range.

Target	*Minimum Range in Yards*
Ship	350-400

Accuracy.

The main source of bearing error, assuming accurate alignment of the bearing indicator, is play in the training gear. This is beyond the control of the ship's personnel, but operators can do much to overcome this play, by lobe-switching to match the pips carefully, and by then feeling for the ends of the backlash motion, and by holding the handwheel as near as possible to the middle of the free motion to read bearings. By this practice, bearings may be read very consistently with a maximum error of 1/4 degree on large steady pips. Range approximately, +/- 25 yards, + .1% of the indicated range.

Resolution.

Bearing: 5 degrees.
Range: 40 yards.

TROUBLES

There are two factors which can cause had bearing readings (other than minor lobe and extended close-in echoes as described previously). These are changes in the transmitter frequency and obstruction, or distortion, of the antenna pattern by periscopes or the SD radar mast. The bearing indicator alignment can be thrown off up to 2 degrees by changes in the frequency, due to shifted tuning of the antenna or internal transmitter adjustments, or by replacement of the magnetron. Whenever any of these troubles occur, bearings should he checked against one or both periscopes. During this check care should be taken that the antenna is not pointing within 30 degrees of the periscope to avoid distortion of the pattern. Presence of a periscope or the SD mast within 30 degrees of the antenna beam can cause varying hearing errors up to some 5 degrees.

It is recommended that each submarine make calibration runs, to provide tables or charts showing the bearing indicator corrections, for conditions of either or both periscopes raised, SD mast raised, and combinations of periscopes and SD mast. It is probable that the charts or tables for some combinations of SD mast and periscopes will he identical. Such information, posted at the operating position, will enable full accuracy to be obtained under all circumstances.

PART 4

SD RADAR

SD RADAR

CONTROLS

Receiver-indicator.

1. *Focus control*: controls focus of the sweep.

2. *Intensity control*: controls brightness of the sweep.

3. *Markers*: allow markers to be put on the scope. Used for obtaining ranges of targets; use of IFF in extreme right position.

4. *Centering*: controls position of the sweep on scope-horizontal positioning.

5. *Stand-by light*: when illuminated indicates power switch is on.

6. *Power switch on-off*: controls AC power applied to the set.

7. *Transmitter plate light* (red): when illuminated indicates switch, No. 14, is on.

8. *Oscillator control*: tunes the receiver to the transmitter frequency.

9. *Sensitivity control*: volume control of the receiver, controls height of the grass and pips.

10. *Fuse F-202-Fuse F-201*: protection for the AC supply.

11. *Scope*: cathode-ray tube.

12. *Transmitter plate current meter*: reading determines setting of the high-voltage variac, No. 15.

13. *Transmitter plate power off-on switch*: controls AC power applied to the high voltage variac, No. 15.

14. *Transmitter plate variac*: controls the amount of DC voltage applied to plates of the transmitting tubes.

15. *IFF gain control*: varies amplitude of IFF signals appearing below the time base.

Transmitter.

1. *Red pilot light*: when illuminated, indicates that the power switch is on at the receiver-indicator unit.

2. *Transmitter plate current meter*: reads the same as meter No. 13 on the receiver-indicator unit.

3. *Filament primary voltage meter*: indicates voltage applied to the primary of the filament transformer, which supplies AC power to filaments of the transmitting tubes.

4. *Filament control variac*: controls the amount of voltage applied to the filament transformer.

5. *Operation hour meter*: registers the total number of hours the set has operated.

6. *Emergency switch off-on*: is in series with main power switch, to be used only in case of emergency.

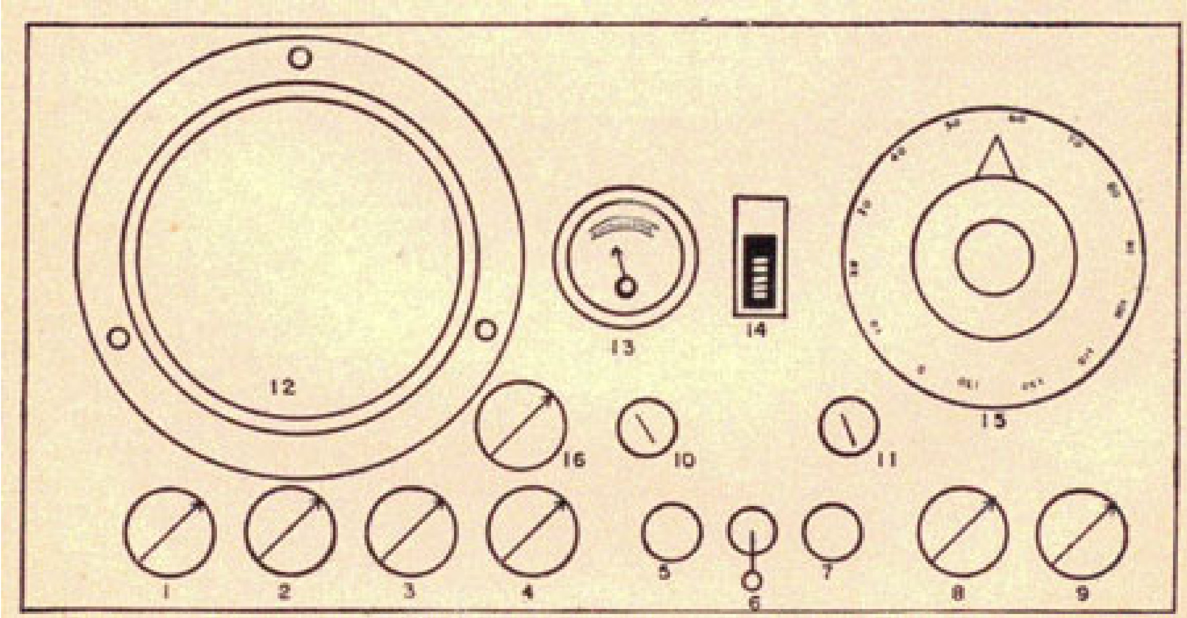

Figure 4 SD-1. Range indicator unit.

4-SD-2

SD RADAR

7. *Diplexer tuning dial*: indicates position of the tuning condenser in the diplexer.

8. *Diplexer tuning control*: varies the position of the condenser in the diplexer: to he set by radar technician.

9. *Exhaust of blower*: maintains cooling for the transmitter.

Diplexer.

(Diplexer unit is to be adjusted by the radar technician only.)

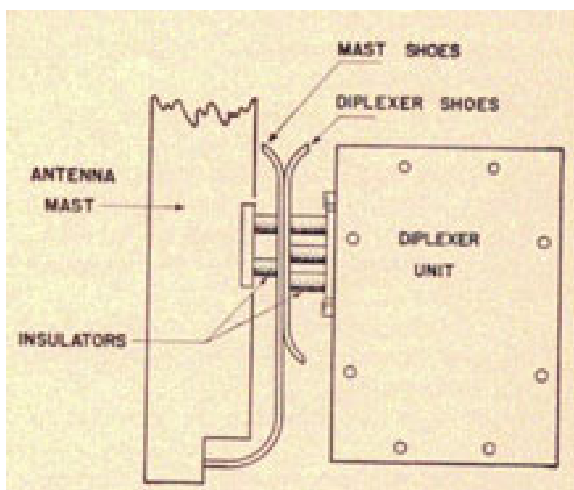

Figure 4 SD-3. Antenna mast and diplexer, with most raised.

TURNING ON AND OFF

Turning an.

1. Check to see that the transmitter plate high

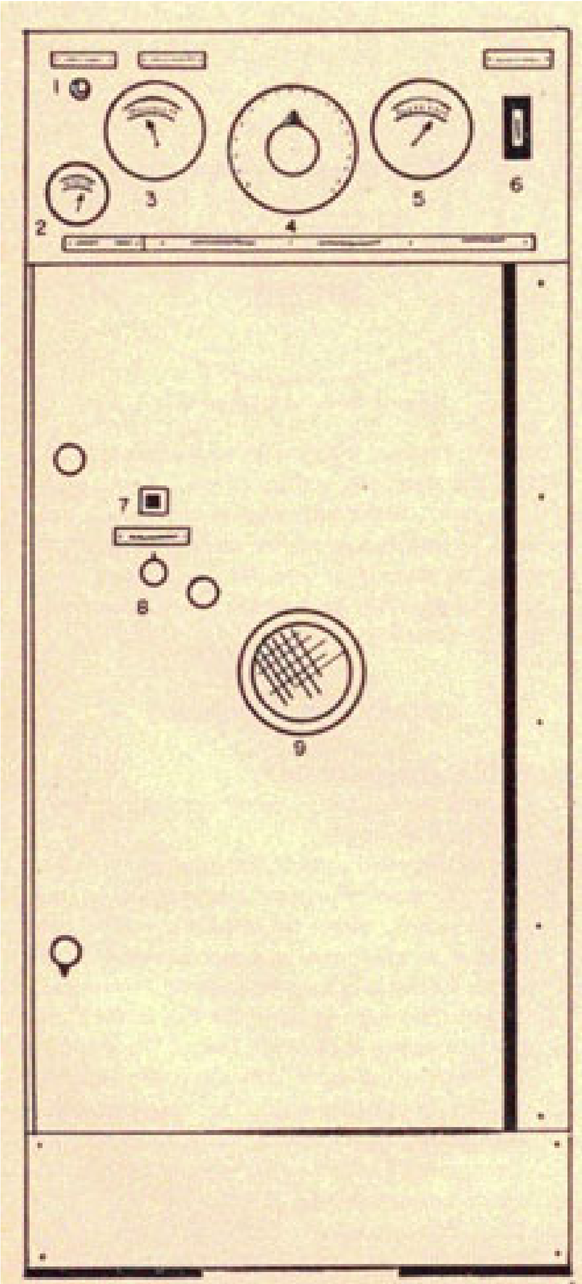

Figure 4 SD-2. Transmitter unit.

voltage switch is off.

2. Turn on the power switch at the receiver-indicator.

3. Red pilot light on the transmitter should illuminate.

4. Check to see that the blower motor in the transmitter is operating.

5. Rotate the primary filament variac slowly clockwise, white watching the filament primary voltage meter increase to a value determined by the radar technician (110 to 120 volts).

6. At the receiver-indicator unit, check to see that the transmitter plate variac and the intensity control are fully counterclockwise.

7. Raise the antenna mast until the top insulators on the mast shoes are even with the top insulators of the diplexer shoes (see fig. 4 SD-3.)

8. Turn on the transmitter high voltage switch on the receiver-indicator unit. Check to see that the red pilot light on the receiver-indicator unit is illuminated.

9. If the line switch has been on for at least 30 seconds, proceed to turn transmitter plate variac clockwise until the plate current meter reads 8 milliamperes (or value specified by technician).

Turning off.

1. Turn the transmitter plate variac to zero.

2. Turn off the transmitter plate switch.

3. Turn off the power switch.

4. Do not touch other controls.

5. Lower the antenna mast.

Abbreviated procedure.

It is suggested that the following controls he left at the proper settings at all times, thus decreasing to a minimum the time required for tune-up:

(1) Filament control variac on the transmitter unit.

(2) Intensity, focus, tuning, sensitivity, and horizontal centering controls on the receiver-indicator unit.

Turning on is then reduced to the following procedure:

(1) Turn on the power switch on the receiver-indicator unit.

(2) Check the green pilot light on the receiver-indicator unit; blower motor in the transmitter, and the filament primary voltage meter on the transmitter.

(3) Raise the antenna mast as described above.

(4) Check to see that the transmitter plate variac on the receiver-indicator unit is at zero.

(5) Turn on the transmitter plate high voltage switch and increase the transmitter plate variac (if just below the sweep line; carefully indicate, in ink. each 2-mile point on the tape (the first marker represents a 2-mile point on the sweep, and each marker thereafter is a 2-mile point).

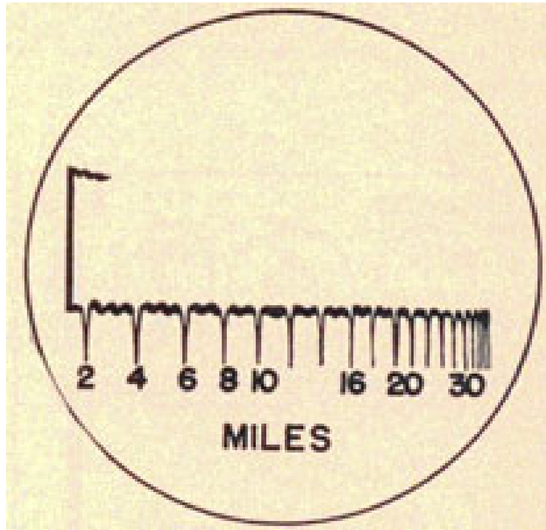

Figure 4 SD-4. Range markers.

Return the marker switch to its normal position, and increase the sensitivity control to read target ranges from the tape. If this arrangement is used, care must be taken to switch markers on and check horizontal centering of sweep each time the set is turned on.

Range markers may he used directly for range measurement if desired.

OPERATIONAL TECHNIQUE

Tuning the equipment.

1. Increase the intensity control until the sweep is visible on the scope.

2. Adjust the, focus control for clearness.

3. With the sensitivity control near minimum (counterclockwise), rotate the oscillator control until a point of maximum response is noted on the scope (increase sensitivity control if necessary).

4. Adjust the sensitivity until the flag at the top of

line switch has been on at least 30 seconds), until the plate current meter on the receiver-indicator unit reads 8 milliamperes (or as specified).

Use of the SD radar before surfacing.

1. The power switch should he on for 10 minutes before using the set.

2. Raise the antenna mast while at periscope depth.

3. When depth decreases to a point at which the antenna is clear of the water (7 to 10 feet), turn on the transmitter plate high voltage switch.

CALIBRATION

Use of markers for range measurement.

With the set properly on and tuned, turn the sensitivity control counterclockwise. Then turn the markers switch to the left, markers should appear on the screen. (Their appearance is illustrated in fig. 4 SD-4.) Place a strip of scotch tape across the screen, the transmitter pulse (left end of the sweep on the scope) is about 1-inch above the base line.

5. Adjust the oscillator control for maximum height of the flag. Now rotate the oscillator control through 360 degrees, checking for another tuning point which may increase the altitude of the flag. Leave the oscillator control on the best tuning point.

6. Increase the sensitivity control until grass appears on the screen. If a steady echo is present, cheek the oscillator tuning for the maximum echo

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height. This check should he made with the sensitivity control adjusted so the echo tuned on is just visible above the grass.

7. Re-check focus.

used as operators. When an operator is standing an SD search watch, he must stay within three feet of the equipment, keeping a *continual* watch on the screen.

Report *all* targets and IFF signals, giving their ranges. Identify the composition of targets, using the following characteristics as a guide to your interpretation of target pips.

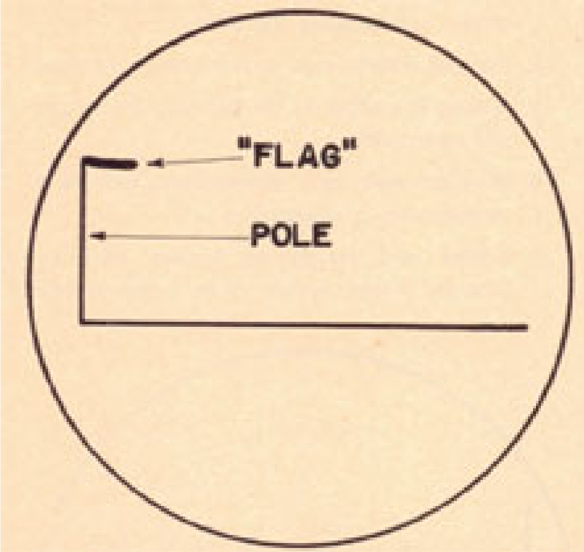


Figure 4 SD-5. Typical appearance of FLAG when properly tuned (sensitivity low).

The appearance of the *flag* at the top of the pulse (left end of the screen) will vary in different sets. Become familiar with the appearance of this flag when properly tuned, and tune for maximum height as well as proper appearance.

If the sweep does not appear immediately on the scope, turn the variac back to zero, and make successive attempts to increase it until a sweep is obtained. The sweep may jump and appear unsteady until water has drained from the antenna, this will cause no damage.

If the depth of the submarine increases to a point where waves may strike the antenna, arcing will occur at the antenna and possibly in the transmitter. Turn the transmitter plate variac to zero if there is a possibility that the antenna will become submerged, and then wait until the proper depth is reached. Quickly check the tuning and range markers, and make reports to the Captain.

It is important in this connection that controls and adjustments on the receiver-indicator unit be left *untouched* while submerged. A check of over-all tuning must he made as quickly as possible during the surfacing procedure.

(1) Land (sharp, fairly steady pip).

(2) Single plane (narrow pip, fuzzy at the top, fading and bouncing rapidly).

(3) More than one plane (wide pip, fuzzy at the top, melting off occasionally on either side from the top, and fading at a slower and more even rate than the single plane pip).

Report any unfamiliar signal or disturbance appearing on the screen. The OOD will immediately call the radar officer or technician to check this interference. Internal interference may come from any AC equipment aboard. External interference may represent jamming or other radar signals.

Caution: When jamming, or other radar interference is encountered, it is likely that your position, or approximate position is already known.

Diving procedure.

When the word "*stand by to dive*" is passed, the operator will perform the following operations:

1. Turn the transmitter plate variac to zero and turn the transmitter plate voltage switch off.

2. Lower the antenna mast.

3. Turn the power switch off.

Care of equipment during long dives.

To minimize troubles or possible damage, due to condensation and moisture, keep the canvas covers on all units; remove and dry these covers frequently if condensation is heavy. Also turn the power switch on (keep the transmitter plate high voltage switch off) for ten minutes every three hours. The controls in the transmitter unit and the receiver-indicator unit

Air search during surface cruising.

Watches of a half-hour duration should be adopted whenever possible. Only those men who have had previous SD radar experience, if available, should be

should not be touched.

PERFORMANCE

Maximum reliable range.

Target	*Range in Mile*
Land 3,000 feet or higher	35
Land 1,000 feet	20
Large planes above 1,000 feet	12-20
Small planes above 1,000 feet	8-15
Low planes	Not detected

Due to the fact that low flying planes will usually not be detected, lookouts must be alert for aircraft flying at low elevations during daylight hours.

Minimum range.

The minimum range on aircraft is about 2,500 to 3,000 yards.

TROUBLES

Trouble is indicated in the SD radar by the following operational difficulties:

1. From 1/4 to 1 1/2 inches of grass are not present at all times when the sensitivity is turned to maximum.

2. Sweep position, intensity, and focus do not remain constant when untouched by the operator.

3. Appearance of the transmitter flag does not remain substantially the same.

4. Internal interference is heavy and persistent.

5. Arcing is audible in the antenna during normal operation.

6. Bi-directional, or a non-uniform pattern of transmission is suspected.

7. Echoes and ranges on known land and friendly planes, appear to be below normal.

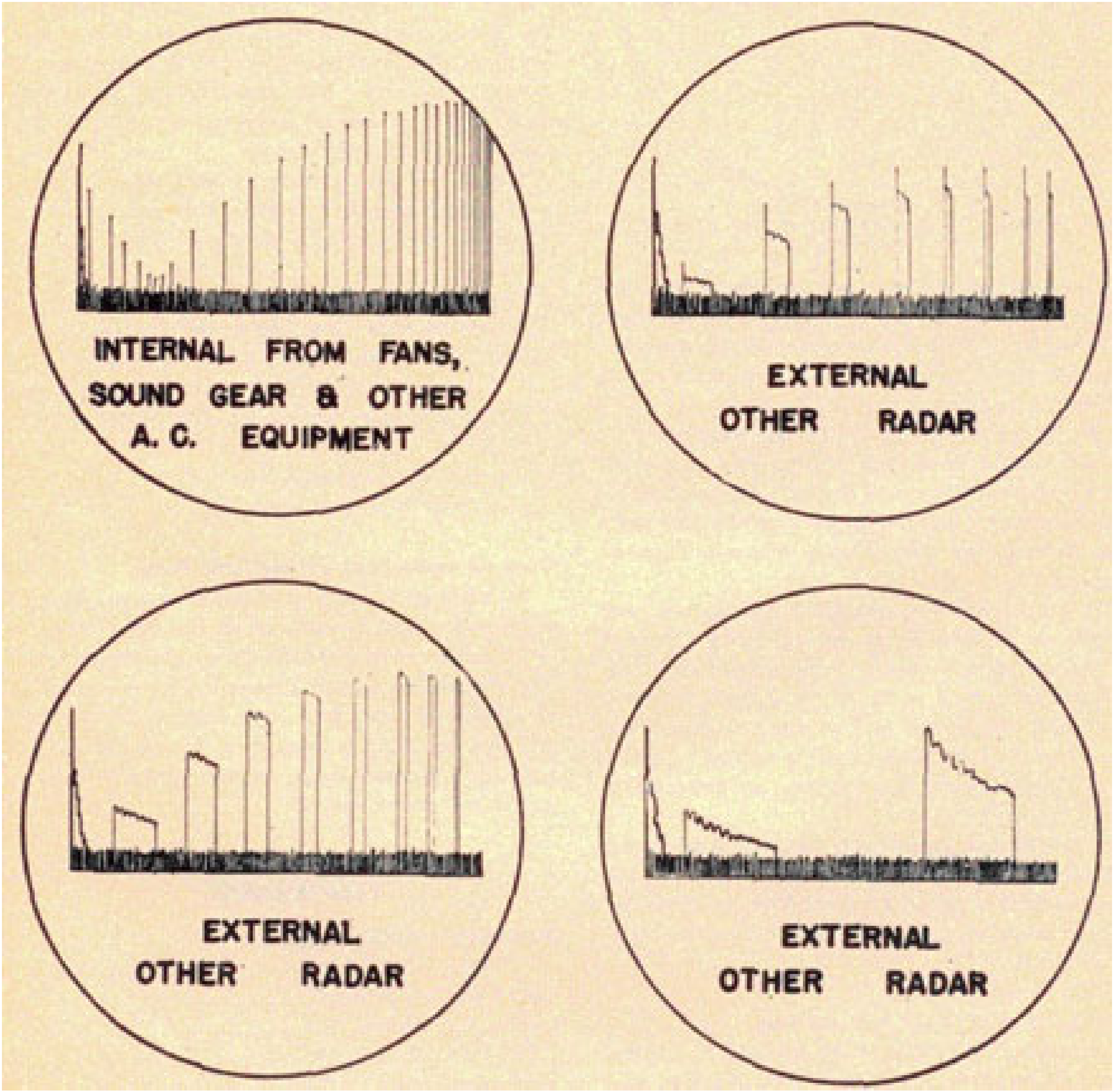


Figure 4 SD-6. Typical screen interference.

4-SD-6

PART 5

RELATIVE MOTION-COMBAT

INFORMATION CENTER

PART 5

RELATIVE MOTION-COMBAT INFORMATION CENTER

RELATIVE MOTION

Note: Plotting symbols and standards may be found in RADFIVE, The Surface Plotting Manual.

COMBAT INFORMATION CENTER

PART 5

RELATIVE MOTION

THE CONCEPT OF RELATIVE MOTION

All of us at one time or another have solved problems in relative motion, probably without recognizing them as such. Crossing a busy street safely, intercepting the player carrying the ball in a football game, running to catch a ball, all of these activities involve a problem in relative motion, even though we do not realize it. In a more complex form, all combat tactics, their determination and execution, deal with relative motion; that which is seen on the radar's PPI scope is relative motion. Hence, it is necessary that all personnel attached to the Combat Information Center, from the operator to the Captain, have a thorough understanding of the varied applications of this important principle.

The basic method of solution of relative motion problems utilizes the maneuvering board, and it is therefore required that all personnel should be capable of using it and applying its solutions.

What is meant by relative motion? It is the resultant of two actual motions, but let us break this down further. The word *motion* implies direction, speed, and distance; relative motion, then, would imply relative direction, relative speed, and relative distance, which are defined as follows:

> *Relative direction* is the apparent direction of one object's movement with reference to another.
>
> *Relative speed* is the speed with which one object moves with respect to another.
>
> *Relative distance* is the distance one object moves with respect to another.

These three definitions then, collectively make up relative motion.

Realizing that relative motion is caused by two actual movements, let us analyze the movement of two objects within the same vicinity. Since we are concerned principally with relative motion as applied to moving ships, imagine two ships in the positions shown in figure 5-2, moving in a general easterly course, during a period of 20 minutes.

The initial position of Ship 1 is at the point *A*. Moving on a due easterly course it arrives at point B 20 minutes later. Picture Ship 2, starting from initial position *a*, which is 2,000 yards astern of Ship 1, and arriving 20 minutes later at position *b*, 2,000 yards broad on the starboard beam of Ship 1.

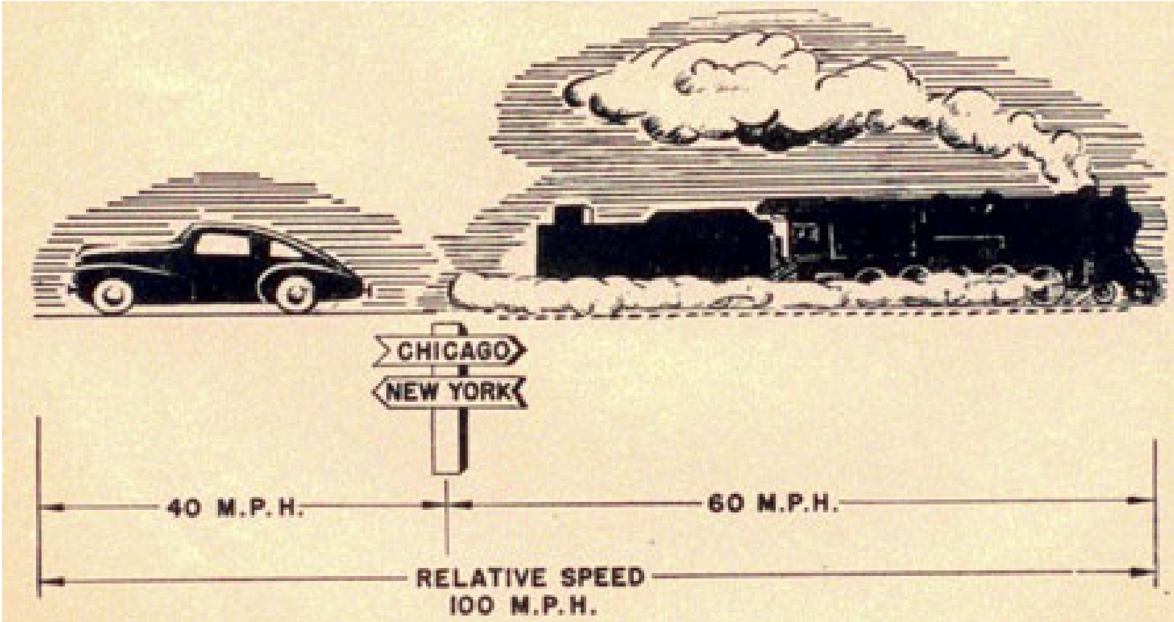


Figure 5-1.

5-2

RELATIVE MOTION

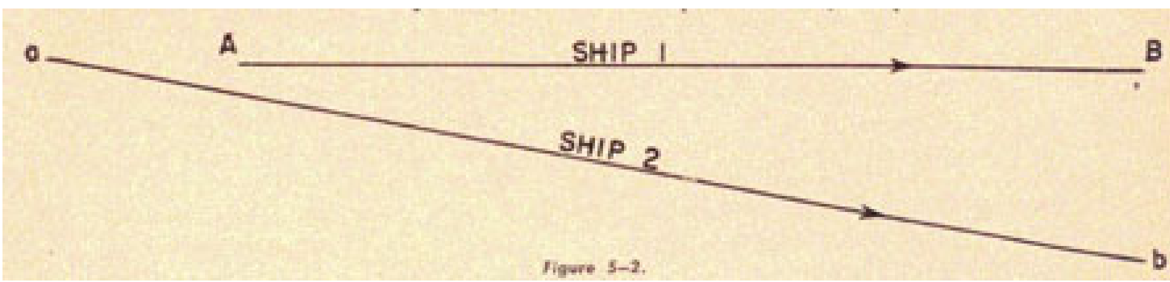


Figure 5-2

Analyzing the original definition of relative motion, it is obvious that these two motions establish a relative motion. If you establish a relative plot of one object with reference to the other, you should be able to ascertain that relative motion. Now, picture yourself on Ship 1, and try to picture what movement Ship 2 would make with reference to you in that 20 minutes. If you (on Ship 1) are moving due east, and Ship 2 is at a position 2,000 yards astern, its initial position would be 270 degrees T at 2,000 yards, at time 00. Ship 2's position after 20 minutes, with reference to you (Ship 1), would be 180 degrees T at 2,000 yards. To establish or form a relative plot, you merely plot successive positions of an object from a stationary point, which represents your position at all times, regardless of the fact that you are

speed = distance/time

speed = 2800/200

speed = 140 yards per minute

Multiply yards per minute by 0.03 and you have miles per hour, or knots. speed = 140 x 0.03 = 4.2 miles per hour.

Therefore, the speed of relative motion would be 4.2 knots.

Examining the direction of the line M_1M_2 you find it to be 135 degrees T. Listing of the information found from the relative plot you have the following:

moving.

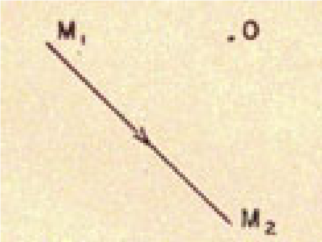


Figure 5-3.

Point *O*, figure 5-3, represents your position at all times, point M_1, the relative position of Ship 2 at time 00, and point M_2, is the relative position of Ship 2 after 20 minutes. By drawing the line from M_1 to M_2 you establish an imaginary line that indicates the apparent movement of Ship 2 with reference to yourself; therefore, the direction of the line from M_1 to M_2 would indicate the direction of relative movement. The length, or distance, of the line would indicate, according to definition, the distance of relative motion during a period of 20 minutes.

If the distance from M_1 to *O* or M_2 to *O* is to represent 2,000 yards, you can measure M_1M_2 using the same scale, and find it to be about 2,800 yards.

Using the formula: *distance divided by time equals speed*, you have:

Direction of relative motion, 135 degrees T
Distance of relative motion, 2,800 yards
Speed of relative motion, 4.2 knots.

You have, therefore, found the three parts of relative motion from the relative plot.

Leaving the relative plot, let us analyze a second method of determining relative motion, which is called the *vector* diagram. The vector diagram is a picture in which we combine the movements of two objects, with respect to a third object, to find their movement with respect to each other. The third object is usually the earth, so that we are really combining two *geographical* movements to find relative motion. To show these movements, geographical or relative, as pictures, we use single lines, called *vectors*. The slope or direction of the vector indicates the direction of the movement it portrays; the length of the vector indicates the speed of the movement. By properly combining two vectors, showing how two objects are moving with respect to the earth, and then drawing the resulting vector necessary to complete a triangle, the resultant side will be the relative movement of the two objects involved. Let us see why that resultant does actually establish the relative motion. Let us suppose you have two objects, the first, moving on a course of 090 degrees at a speed of 12 knots, and the second, in the same vicinity, moving on a course of 150 degrees at a speed of 15 knots, as shown in figure 5-4.

RADAR OPERATOR'S MANUAL

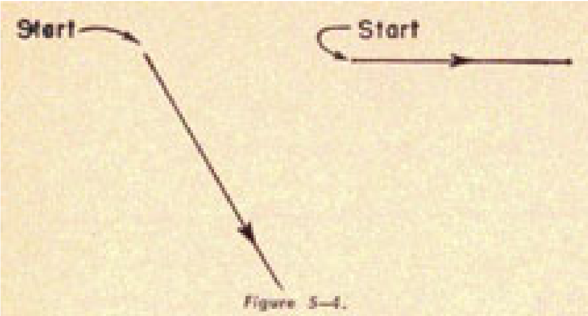


Figure 5-4.

If you should form a relative plot of these two moving objects for a full hour, as shown in figure 5-5, you would get the line *XY*.

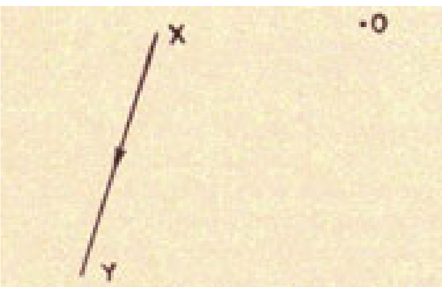


Figure 5-5

From what you know of the relative plot, you realize that the direction of *XY*, is the direction of the relative motion; the length of *XY*, is the distance of relative motion; and the time interval in this case is one hour.

But what is the distance per hour? It is speed. Therefore, the length *XY*, is the speed of relative motion. Suppose you move the position of the second ship so that it moves from some other position with the reference to Ship 1, but remains on the same course and at the same speed, as shown in figure 5-6.

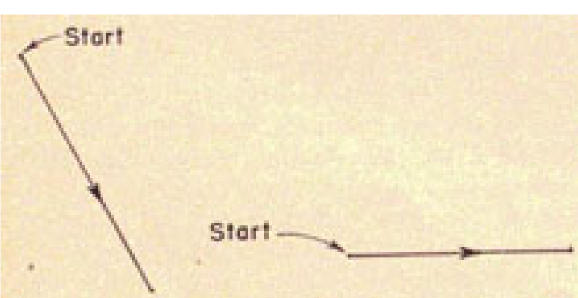


Figure 5-6.

By the same deductions as used in figure 5-5, we find the direction of relative motion and the distance of relative motion in one hour, which is the speed of relative motion. By comparison, we find that X_1Y_1 is the same direction and represents the

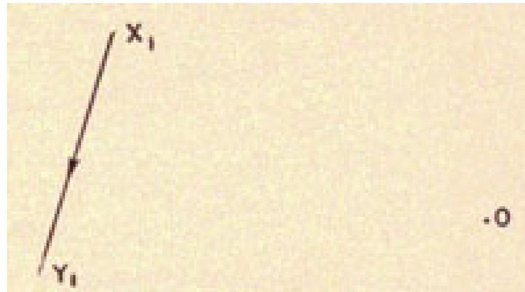


Figure 5-7.

same speed as *XY*. So, let us start Ship 1 and Ship 2 on the same courses and speeds as before, but from a common point, as shown in figure 5-8.

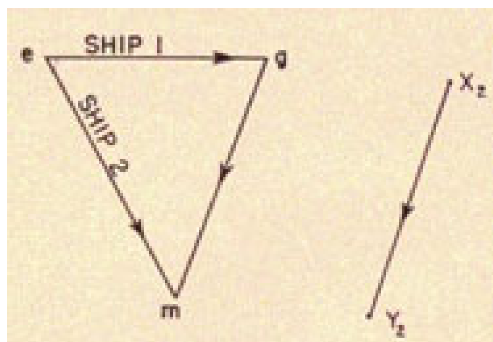


Figure 5-8.

If you establish the relative plot, you find that X_2Y_2 is in the same direction as *XY* and X_1Y_1 and the same length as *XY* and X_1Y_1. Likewise, if you connect the terminal positions of Ship 1 and Ship 2 (points *g* and *m*) you find that the line is also in the same direction and the same length as *XY* and X_1Y_1. Therefore, it appears unnecessary to form the relative plot, when course and the speeds of two moving objects are known. Instead, you can draw two lines which indicate direction and speed, that is, draw two vectors from a common point; then by connecting the ends of those vectors you will find the resulting vector, which represents the direction and speed of

Figure 5-7 is made by forming the relative plot of figure 5-6 and we get the line X_1Y_1.

relative motion. This triangle, which is called the vector diagram, and labeled *egm*, as shown in figure 5-8, is the solution of two actual motions, namely *eg* and *em*, which produces the resultant *gm*. This resultant is the direction and

speed of relative motion. At this point, let us sum up what is represented by the various vectors of the vector diagram, *egm*.

eg represents the course and speed of the unit to which the relative motion is referred, or the guides course and speed. The course being indicated by the direction of *eg*, and the speed being indicated by the length of *eg*.

em represents the course and speed of the second moving object, or the maneuvering unit's course and speed, the course being indicated by the direction of *em*, and the speed being indicated by the length of *em*.

gm represents the relative motion with reference to the guide ship, that is, the direction from *g* to *m* represents the direction of relative motion, and the length of *gm* indicates the speed of relative motion.

USING THE MANEUVERING BOARD

Figure 5-9 is a standard Navy maneuvering board. Notice that it is a polar coordinate system,

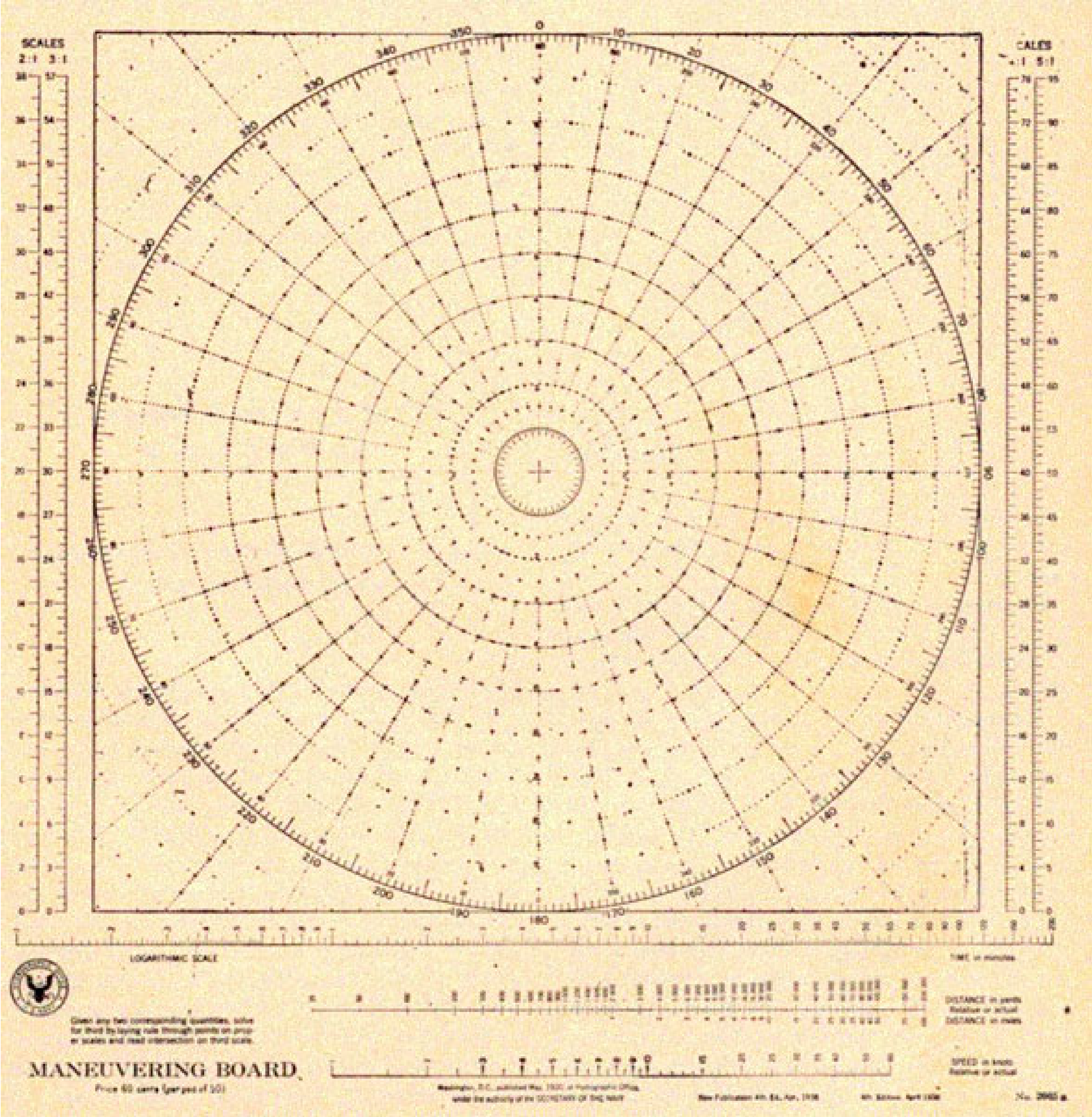

SCALES
MANEUVERING BOARD
LOGARITHMIC SCALE
TIME in minutes
SPEED in knots

Figure 5-9.

that is, divided into 360 units or degrees. This will enable you to establish or indicate any direction whatsoever, in degrees, on a true basis. The outer numbers indicate the true direction, whereas the inner numbers will indicate the opposite, or reciprocal direction.

The maneuvering board is made up of ten concentric circles, that is, ten circles having the same center. You can therefore indicate any speed or distance desired, by choosing the proper scale. If a 1/1 scale is chosen, you can indicate any speed from 1 to 10 knots. If you choose a 2/1 scale, you can indicate speeds up to 20 knots. etc.

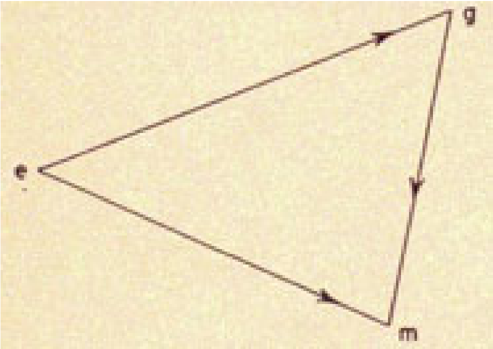


Figure 5-10.

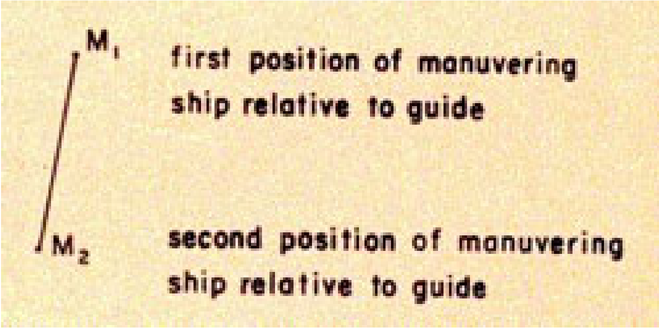
In representing distances, use scales such as 1 unit is equal to 2,000 yards, or 1 unit is equal to 3,000 yards, etc.

The scales on the left and right of the board, that is 2:1, 3:1, 4:1, and 5:1, are simply aids to be used in computation in accordance with whatever scale is chosen.

The logarithmic scales, at the bottom of the chart, that indicate time, distance, and speed, are so placed as to enable you to solve problems of time, distance, and speed, merely by drawing a straight line. For example, if you know that an object has traveled 3 miles in 10 minutes, you can place a point on the distance scale at the position that indicates 3 miles, and

It must be realized, that if you use time and relative distance, or relative speed, the result will be relative speed or relative distance. Likewise, if you use actual distance, or actual speed with time, the result will represent actual speed or actual distance.

If you are requested to draw the vector diagram *egm* on a maneuvering board, obviously, the simplest procedure is to place one of the angles of the triangle at the center of the chart. For the sake of consistency, let us say that we will always place point *e* at the center of the chart. This point *e* has no meaning by itself; it is merely the point at which two vectors are joined. It is absolutely incorrect to think of the guide as moving from *e* to *g* during the maneuver; he does not. The line *eg* shows the direction and speed of the guides movement over the earth; it in no way indicates his starting point or final position. Naturally, whatever scale is used to represent the speed of the guide, must be consistently used in the representation and interpretation of *eg*, *em*, and *gm*. Going back to the relative plot, you realize that you have established the position of M_1 and M_2 with



reference to the guide's position, ignoring the movement of the guide, it would be possible to draw this relative plot on the same maneuvering board, even though the relative plot and the vector diagram are two different problems. Since they are different problems, it is possible to use a scale in the relative plot different from that which was used in the vector diagram. In order to keep in mind which scale you are using for *egm* (the vector diagram) and which for the relative plot, it will be helpful to label the scales. In the illustrations, notice that the distance scale is marked *D* and the speed

on the time scale at the position that indicates 10 minutes. By drawing a line through those points and extending it until it intersects the speed scale, you will find that it crosses the speed scale at 20 knots. That is, the object is traveling at a speed of 20 knots. Obviously, the care with which you establish your points and draw your line has a direct bearing on its accuracy.

scale is marked *S*.

Examining figure 5-10, which is a relative plot and a vector diagram, notice that the line *gm* is parallel gm represented the direction of relative motion. It to the line M_1M_2. It has been shown that the line

has also been shown, that M_1M_2, represents the direction of relative motion. If both lines are to represent the same direction, it is obvious that they must be parallel.

In geometry if you have two sides and the included angle of a triangle, you are able to establish the third side. That is, if you know the direction of two sides of a triangle and the length of those sides, it is an easy matter to find the third side. Therefore, knowing *eg* and *em*, *gm* can be found by connecting the points *g* and *m*. Likewise, if you know *eg* and the direction and length of *gm*, it is simple to find *em*.

In cruising at sea, you should always know or be able to find one line of the vector diagram, since you always know your own course and speed. You could establish or start a vector diagram by drawing the line *eg* to represent your course and speed, choosing an appropriate scale in accordance with the speed. If you pick up a contact bearing 280 degrees at 24,000 yards, you could establish point M_1, and report a contact at that position with reference to your ship.

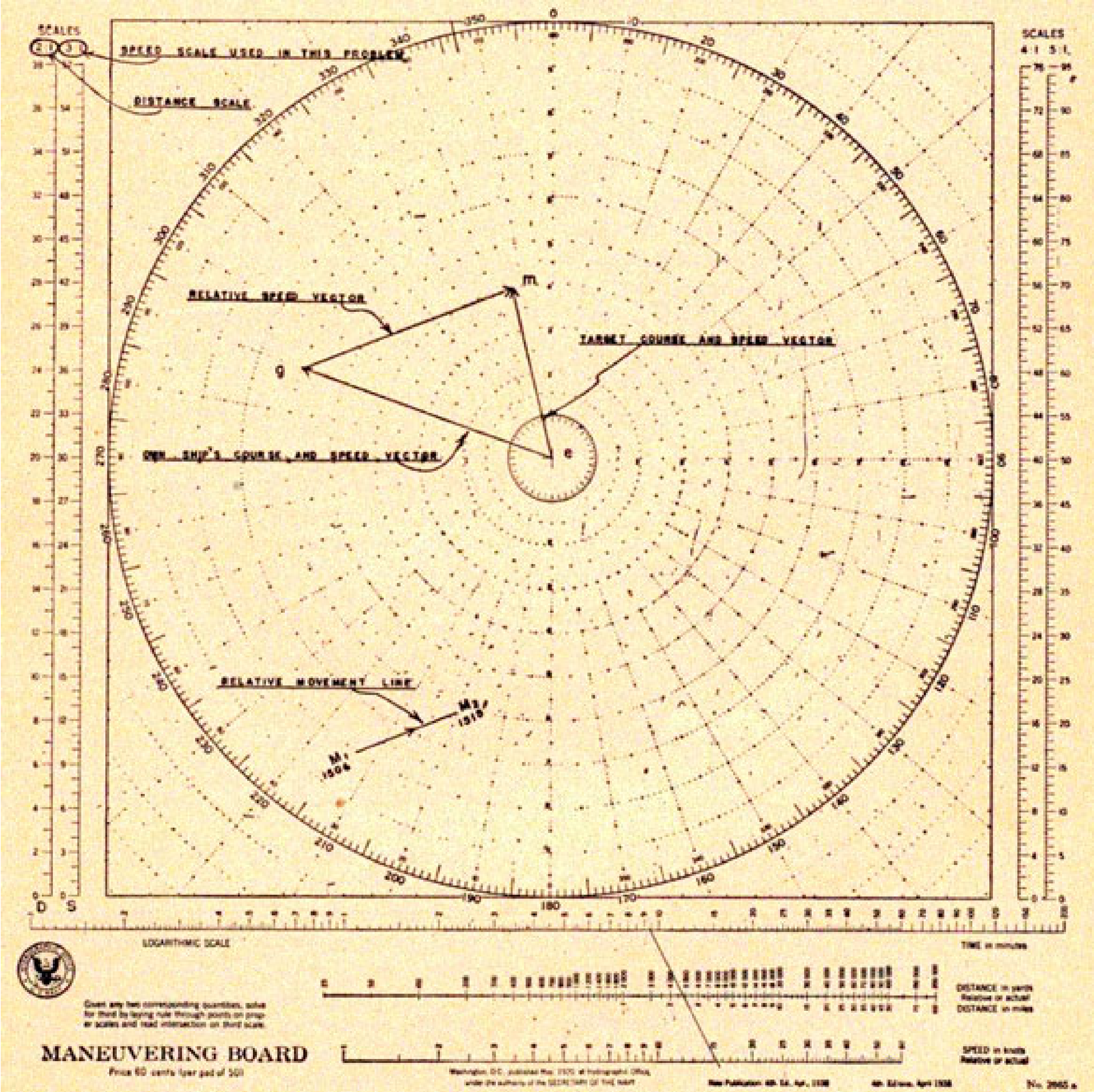

SCALES
SPEED SCALE USED IN THIS PROBLEM
DISTANCE SCALE
RELATIVE SPEED VECTOR
TARGET COURSE AND SPEED VECTOR
OWN SHIP'S COURSE AND SPEED VECTOR
RELATIVE MOVEMENT LINE
m
g
e
M1 1506
M2 1519
D
S
LOGARITHMIC SCALE
TIME in minutes
DISTANCE in yards Relative or actual
DISTANCE in miles
SPEED in knots Relative or actual
MANEUVERING BOARD

Figure 5-11.

Now that you have found the contact before getting too close, the next step is to establish exactly what the contact is doing, or in terms of the diagram, the length and direction of the line *em*.

How can that be determined? If the relative motion between your own ship and the contact is known, you can draw the line *gm* and therefore establish the line *em*. Then you can report what the contact is doing. How can you find the relative motion? Having established a relative plot, you can find M_1M_2, which tells all you need to know about relative motion. You recall, that to form the relative plot, you need to know a series of successive positions of the contact with respect to your ship. Where can you get this information? The answer is the radar. The radar tells where the unit is with reference to your ship, so you can establish in a short period of time a relative movement line M_1M_2 (M_2 being a later relative position than M_1). Thus, M_1M_2 forms the relative plot. Let us say that M_1M_2 is the direction of relative motion. Therefore, you are able to draw the line from *g* parallel and in the same direction as M_1M_2. Since the length of *gm* is determined by the speed of relative motion, you must next find the speed of relative motion. By measuring M_1M_2. which gives the distance of relative motion, and applying that distance and elapsed time between M_1, and M_2, in the formula $D=RT$, you find the speed of relative motion. Using the same scale that was chosen when *eg* was established, lay off the distance from *g* to *m*, making it equal to the speed of relative motion. This established the point *m*. By drawing the line from *e* to *m* you can tell the course of the contact by the direction of *em*. The length of *em*, according to the established scale, represents the speed of the contact. The information is now ready to be reported, and together with the operator's interpretation of the composition, will enable the proper decision to be made in regard to combatant tactics.

ILLUSTRATED EXAMPLES

Finding course and speed of the maneuvering ship.

Suppose you are cruising along on a course of 290 degrees, at a speed of 18 knots. At 1506 you pick up a contact at a bearing of 213 degrees and at a range of 16,000 yards At 1515[2] the contact has moved to a position of 200 degrees, 12,400 yards away from you. Your problem is to find the contact's course and speed.

Procedure	Reason for Procedure
1. Choose a scale of 3 knots = 1 unit, to establish the vector diagram.	1. Make the *egm* triangle as large as possible to insure greater accuracy of measurement. Using 3:1 scale you can represent speed up to 30 knots.
2. Draw *eg* on 290 degree line and 6 units in length.	2. *eg* represents your own course and speed which is 290 degrees at 18 knots. 18 / 3=6 (3:1 scale).
3. Choose a scale of 2,000 yards = 1 unit, for the scale of relative plot.	3. Again you want the largest scale possible for accuracy. A scale of 2,000 yards = 1 unit will allow you to plot points within 20,000 yards on your board.
4. Plot M_1 at 213 degrees at 8 units from *e*. Label and time.	4. The contact was at 213 degrees at 16,000 yards from you at 1506. Your position is considered to be at the center at all times. 16,000 / 2,000 = 8 (2,000:1 scale).
5. Plot M_2 at 200 degrees at 6.2 units from *e*. Label and time.	5. The contact was at 200 degrees at 12,400 yards from you at 1515^2. 12,400/2,000=6.2.
6. Draw M_1M_2.	6. M_1M_2 represents the direction of relative motion.
7. Draw a line from *g* parallel to and in the same direction as M_1M_2.	7. The line from *g* to *m* is also the direction of relative motion, so *gm* is parallel to M_1M_2.
8. Measure M_1M_2, and find the distance of relative motion, using 2,000 yards to 1 unit scale. Distance of relative motion 4,800 yards.	8. To find where *m* falls on the line from *g*, recall that the length of *gm* is determined by the speed of relative motion. To find relative speed, solve relative distance with time in the formula D = RT (D = distance, R = speed, T = time).

RELATIVE MOTION

Procedure	Reason for Procedure
9. Time interval of relative plot is 9 1/2 minutes.	9. 1515^2 - 1506 = 9 1/2 minutes.
10. Speed of relative motion is 15 1/4 knots.	10. Using 4,800 yards distance of relative motion and time 9 1/2 minutes, according to instructions, the line crosses speed scale at 15 1/4 knots.
11. Lay off *gm* 15 1/4 knots. (3:1 scale).	11. *gm* represents the speed of relative motion by its length. 3:1 scale was established in Step 1 for vector diagram.
12. Draw *em*.	12. The two points fix the line *em*.
13. Course of contact is 347 degrees.	13. Direction of *em* gives course of maneuvering unit.

14. Measure *em* of 3:1 scale. Contact's speed is 12 knots.	14. Length of *em* furnishes speed of maneuvering unit.

The foregoing problem furnishes a means of determining the course and speed of a radar contact; We must realize, however, that this method has limitations and for this reason often may not be the best and simplest solution. Sometimes it is the only means available, unfortunately, and we should, therefore, master it thoroughly.

Let us consider some of the disadvantages of figuring course and speed of a radar contact by this method. For one thing, the solution is correct only when our ship remains on a steady course and speed throughout the period of time used to form the relative plot. Furthermore, if the relative speed is slow, it requires a greater period of time to establish a relative plot that is large enough to measure with any degree of accuracy. In forming a relative plot, a change of speed is not easily detected. This increases the possibility of error in the solution of the contact's speed.

If there is a DRT (Dead Reckoning Tracer) available, it will furnish information more quickly than a maneuvering board in this problem. It is a good idea, however, to check the DRT solution by the maneuvering board when possible, to see that the mechanics of the DRT are functioning correctly.

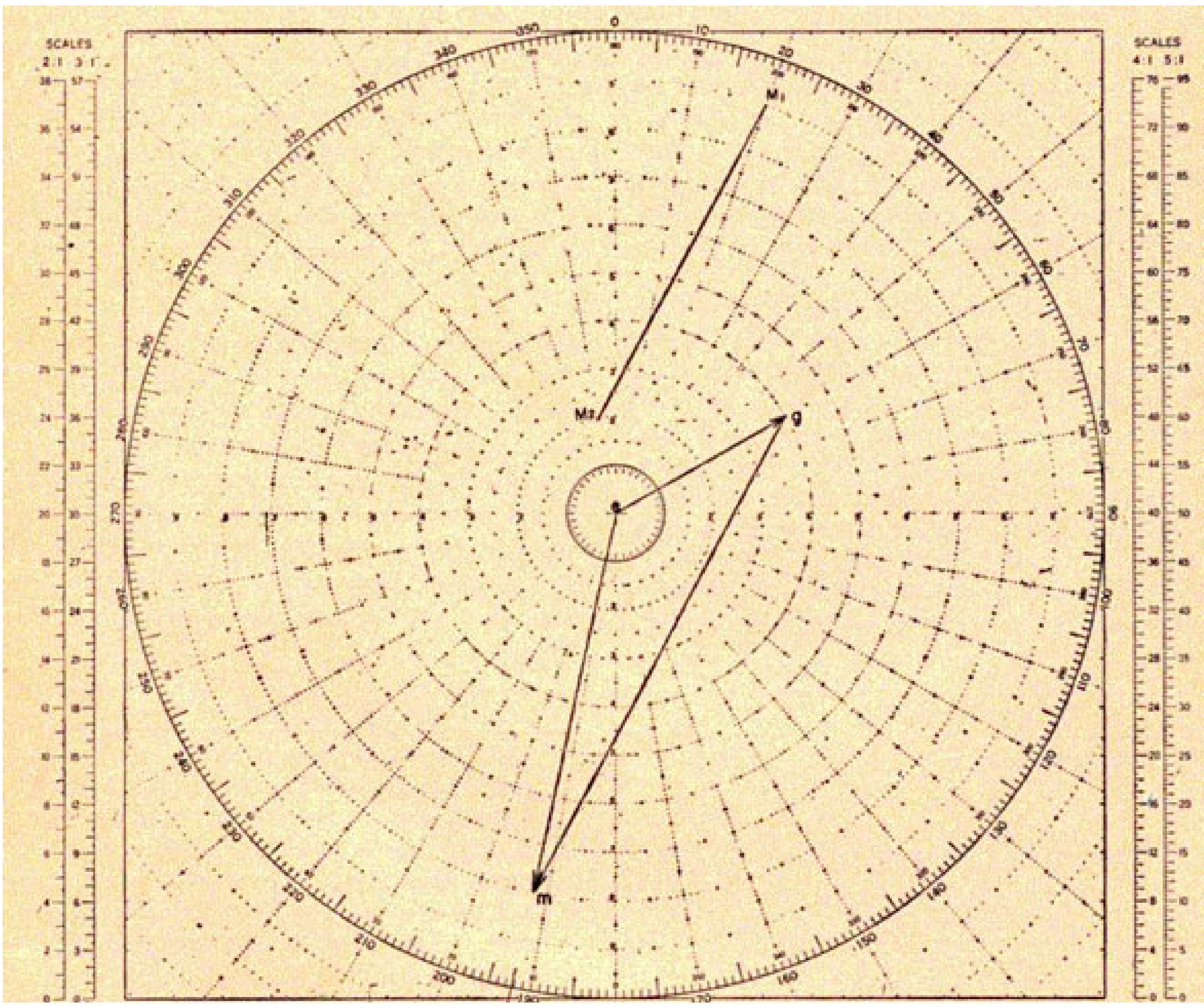
Maneuvering to attack position.

Suppose you have picked up a contact and have determined that it is traveling on a course of 060 degrees at a speed of 12 knots. The contact bears 200 degrees, at a range of 18,000 yards from your ship. Your task is to figure out a course to maneuver your ship to an attacking position, 70 degrees off the port bow, at a range of 4,000 yards, using a speed of 24 knots, and the time that will be required to accomplish this maneuver.

Procedure	Reason for Procedure
1. Choose the scale of 3:1 for vector diagram.	1. Since you must represent speeds of 24 knots and 12 knots you will use a 3:1 scale, because it is the largest scale possible in this case.
2. Draw *eg* on a course of 060 degrees four units long. (3:1 scale).	2. Since you are to make the maneuver, you will he the maneuvering ship, therefore, the contact will have to be the guide. Contact's course is 060 degrees, speed is 12 knots 12 / 3 = 4 (3:1 scale).
3. Choose the scale of 2,000:1 for relative plot. Plot M_1 at 020 degrees, nine units from *e*.	3. If the contact bears 200 degrees from your ship, you obviously bear 020 degrees from him, He is now guide, so you use 020 degrees. Scale 2,000:1 is the largest scale capable of representing 18,000 yards. 18,000 / 2,000 = 9.
4. Using the 2,000:1 scale, plot M_2 at 350 degrees, two units from *e*.	4. If the contact is on course 060 degrees and you desire to be 70 degrees on his port bow: 060 degrees - 70 degrees = 350 degrees. 4,000 / 2,000 = 2.

RADAR OPERATOR'S MANUAL

Procedure	**Procedure**
5. Draw M_1M_2.	5. M_1M_2 gives the direction of relative motion and the distance of relative motion.
6. Draw a line from *g* parallel to M_1M_2 and in the same direction as M_1M_2.	6. The line from *g* to *m* will represent the direction of relative motion. It is therefore, parallel to and in the same direction as M_1M_2.
7. Where the line from *g* intersects the 8th circle, label *m*.	7. You know that *m* must fall somewhere on the line from *g*. Since you are the maneuvering unit, and your speed is to be 24 knots, the line *em* must be 24 knots long, or 8 units long, using



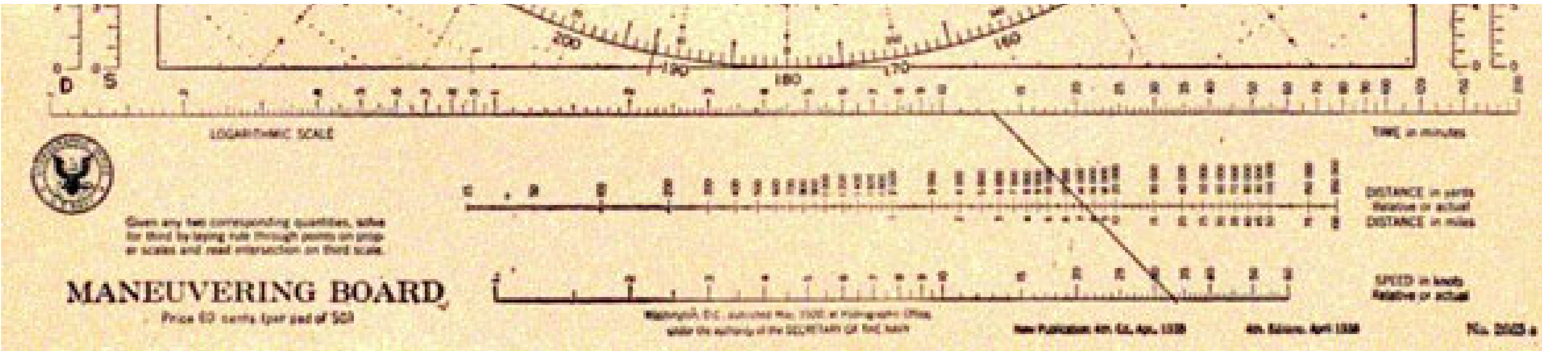


Figure 5-12.

5-10

RELATIVE MOTION

Procedure	Reason for Procedure
	a 3:1 scale. The point at which the 8th circle crosses the line from *g* is the only one that satisfies both conditions.
8. Draw *em*, your course and speed. That is 192 degrees at 24 knots.	8. *em* is the maneuvering unit's course and speed.
9. Find the distance of relative motion by measuring M_1M_2, or 2,000:1 scale. Distance relative motion, 14,600 yards.	9. M_1M_2 represents the distance of relative motion and is 7.3 units long. 7.3 x 2,000 = 14,600.
10. Find the speed of relative motion by measuring *gm* on 3:1 scale. Speed of relative motion is 33.3 knots.	10. *gm* represents the speed of relative motion and is 11.1 units long. 3 x 11.1 = 33.3.
11. Time required to make maneuver is 13 minutes.	11. Continuing your solution at the bottom of the chart you find that the line determined by the points of 14,600 yards on the distance scale, and 33.3 knots on the speed scale, crosses the time line at 13 minutes if extended.

The preceding maneuvering problem and variations of that problem are the most frequently used in CIC operations. Ships moving in company often are ordered to make certain maneuvers within the force for various purposes, such as refueling, searching areas, changing station, or allowing aircraft carriers to launch planes. Placing attacking ships in the best strategic position to engage the enemy forces, also requires this type of a solution.

Simple torpedo problem.

Assume you are on the necessary course and traveling at the proper speed to arrive at a position 5,000 yards and 60 degrees off the starboard bow of an enemy vessel, which has been determined to be on a course of 163 degrees at a speed of 15 knots.

Upon arriving at that position, your ship is to fire a 27-knot torpedo at the enemy ship. What course should the torpedo be set on?

Procedure	Reason for Procedure
1. Draw *eg* in the direction of 163 degrees and 5 units long, using 3:1 scale for speed.	1. The torpedo will have the role of the maneuvering unit. The enemy ship is considered as the guide. His course is 163 degrees; his speed is 15 knots. 15 / 3 = 5 units.
2. Establish M_1, at point 223 degrees and 5 units from *e* using 1000:1 scale.	2. Your firing position is 60 degrees off the starboard bow of the enemy at a range of 5,000 yards. 163 degrees + 60 degrees = 223 degrees; 5,000 / 1,000 = 5.
3. Establish M_2 at the center.	3. You want the torpedo to hit the enemy, at the center in relation to your ship.
4. Draw a line from *g* in the direction established by M_1 to M_2.	4. M_1M_2 is the direction of relative motion and *gm* also the direction of relative motion. Point *m* must also be on that line.
5. Where the line from *g* intersects the 9th circle place point *m*; draw *em*, the torpedo's course and speed.	5. You know *em* must be 9 units long to represent 27 knots, the speed of your torpedo. The point of intersection is the only point on the line from *g* which satisfies that condition.
6. Torpedo course is 072 degrees, speed 27 knots.	6. *em* represents the maneuvering unit's course and speed.

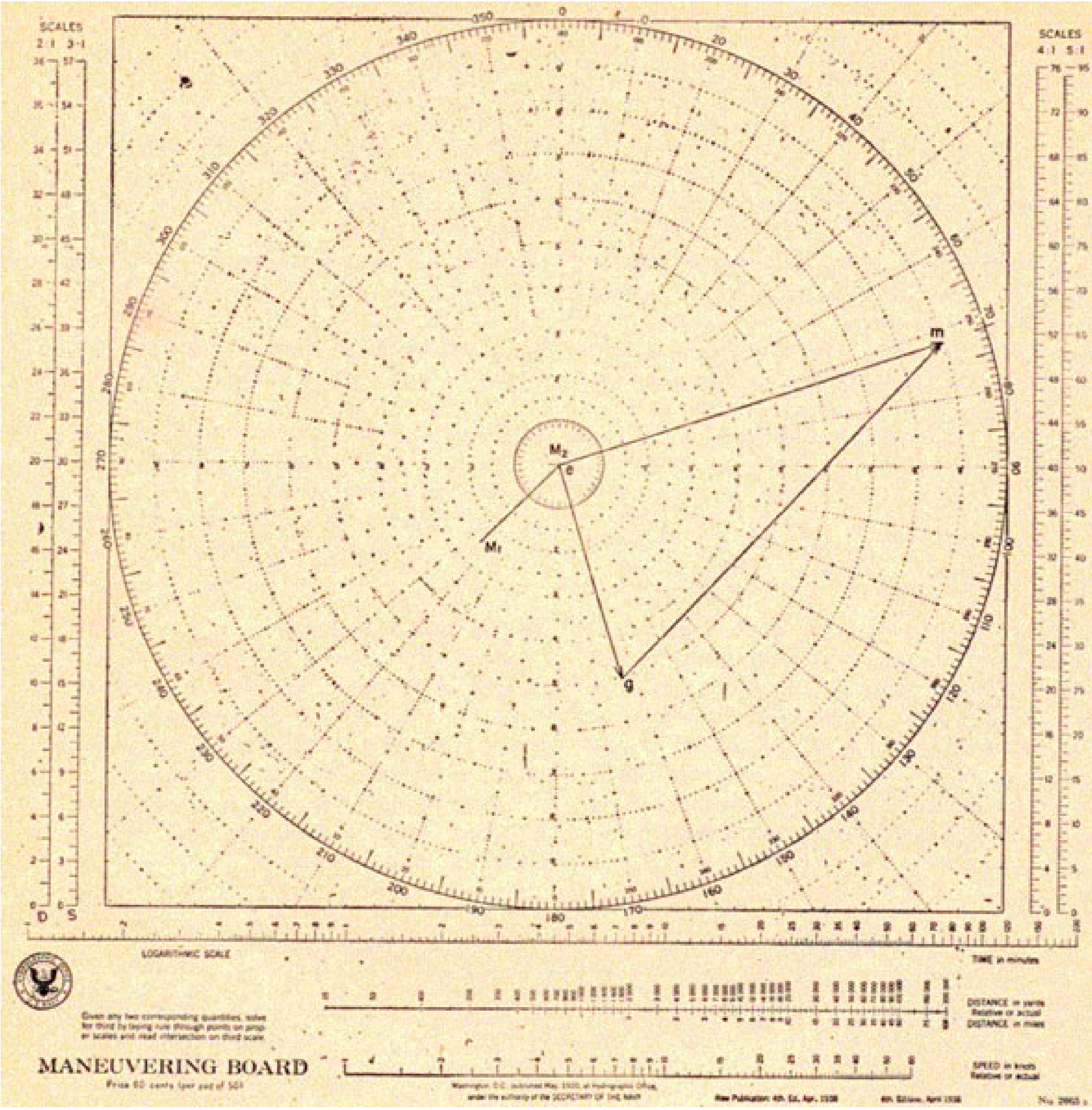


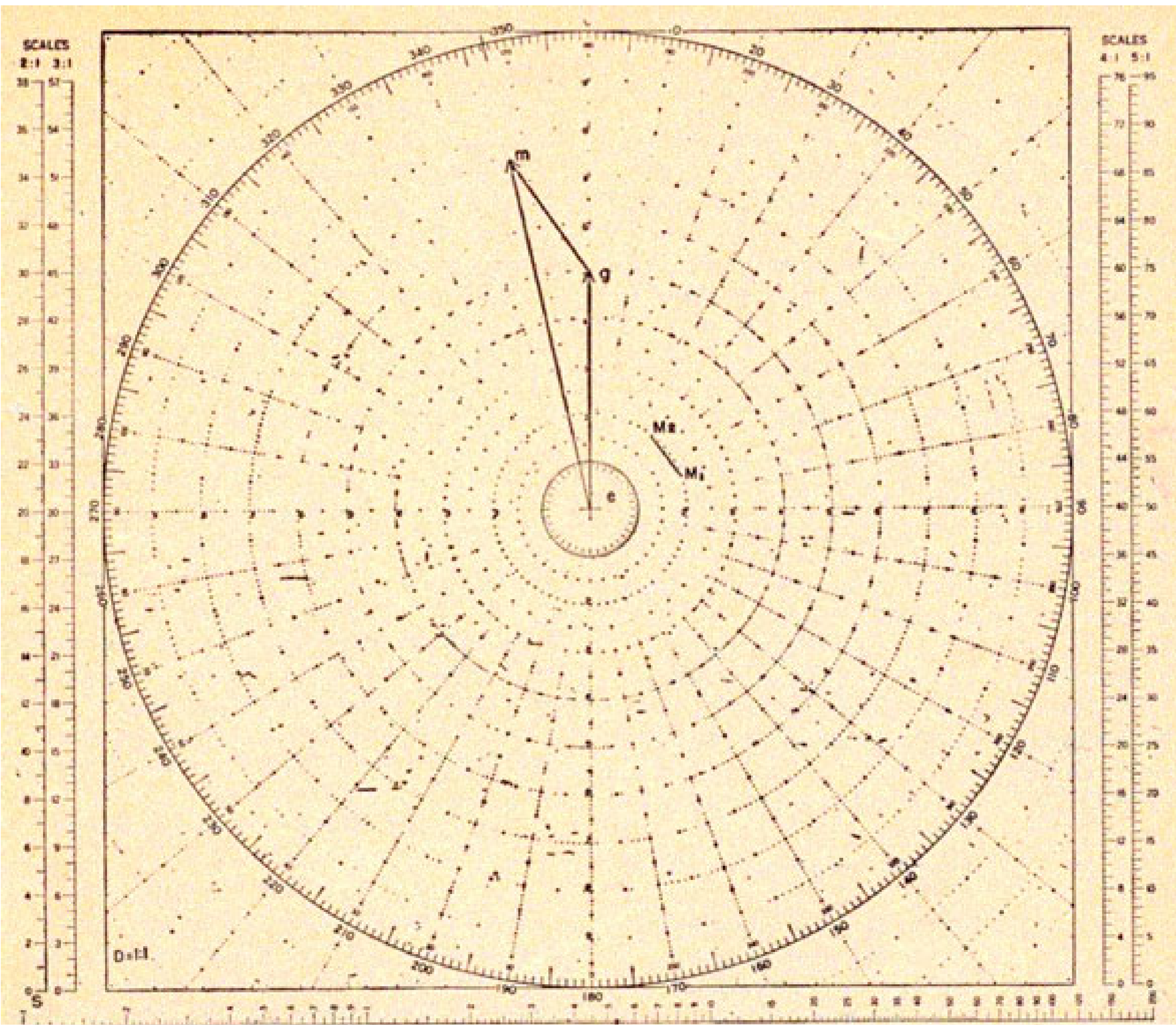
Figure 5-13.

Station keeping.

A convoy is on a base course of 030 degrees at 10 knots. Your position is 40 degrees relative, at a range of 2,000 yards from the guide. At 1400, guide makes an emergency turn to 000 degrees course. You are to use 15 knots to return to station. What course do you take? At what time will you be back on station?

Procedure	Reason for Procedure
1. Draw *eg* on 000 degrees, 5 units in length, 2:1 scale.	1. As long as guide is on course 030 degrees, you are on station, but when he turns to 000 degrees you are out of position and must return to proper station. Guide's speed is 10. 10 / 2 = 5 (2:1 scale).
2. Establish M_1 at 070 degrees, 2 units from *e*. (1,000:1 scale).	2. Your position was 40 degrees beyond original course of 030 degrees at a range of 2,000 yards. 2,000 / 1,000 = 2.

RELATIVE MOTION



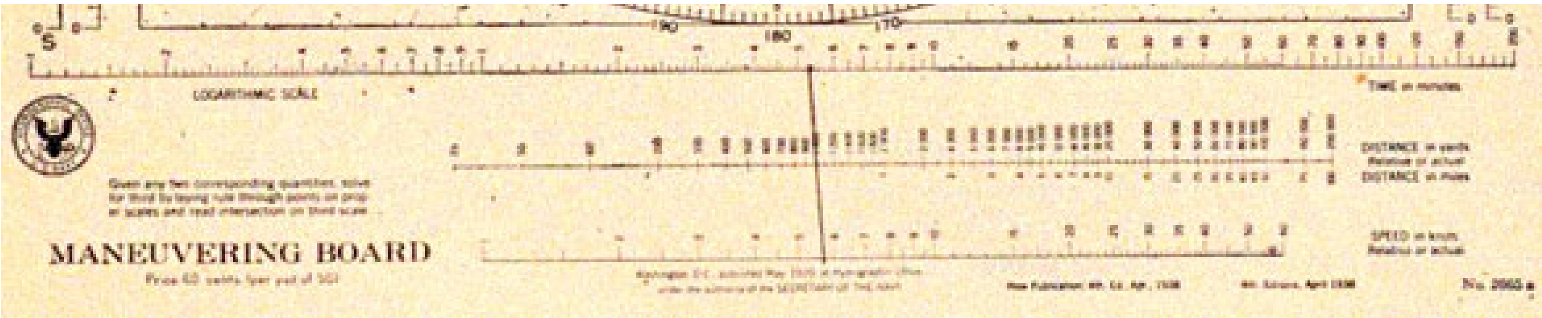


Figure 5-14.

Procedure	Reason for Procedure
3. Establish M_2, at 040 degrees, 2 units from *e*.	3. When guide comes to course 000 degrees you wish to come to a position 40 degrees from the guide at a range of 2,000 yards. 2,000 / 1,000 = 2.
4. Draw M_1M_2, in the direction of relative motion.	4. M_1M_2 determines the direction of relative motion.
5. From *g* draw a line parallel to and in the same direction as M_1M_2.	5. *g* to *m* is also the direction of relative motion and in must be on that line from *g*.
6. Where the line from *g* crosses the circle, 7 1/2 units from *e*, establish point *m* and draw *em*.	6. *em* must be 7 1/2 units long as your own (the maneuvering unit's) speed is to be 15 knots for the maneuver. 15 / 2 = 7 1/2. (2:1 scale).

Procedure	Reason for Procedure
7. Required course is 347 degrees speed 15 knots.	7. *em* is in direction of 347 degrees and 7 1/2 units long.
8. Measure the length of M_1M_2 on the 2,000:1 scale. Relative distance is 1,050 yards.	8. M_1M_2 is the distance of relative motion and is 1,050 yards in length. (2,000:1 scale).
9. Measure *gm* on 2:1 scale; speed of relative motion is 5.7 knots.	9. *gm* is the speed of relative motion, and is 5.7 knots in length. (2:1 scale).
10. Solving on the scales at the bottom of the chart, we find the time required to return to station is 5 1/4 minutes.	10. Relative distance divided by relative speed results in time.

PRACTICE PROBLEMS

The following problems of average difficulty are for practice in use of the maneuvering board.

1. You are traveling on course 120 degrees at 16 knots. At 0405 you pick up a contact at 236 degrees, range 16,000 yards. At 0411 the contact bears 239 degrees at 19,000 yards. What is the course and speed of the contact?

   ans. 187 degrees-12 knots

2. Your ship is on course 070 degrees at a speed of 18 knots. At 0316 there is a contact at 050 degrees, range 18,000 yards. After tracking the contact for 9 minutes, he then bears 058 degrees at 13,000 yards.
REQUIRED:

   (a) What is the contact's course and speed?
   (b) Contact's course and speed at 0328?
   (c) What range will he be on when he crosses dead ahead of you?
   ans. (a) 142 degrees-12 1/4 knots
   ans. (b) 062 degrees-11,400
   ans. (c) 9,500

3. A freighter is traveling on a course of 025 degrees at a speed of 10 knots, An enemy destroyer is on a course 115 degrees at a speed of 20 knots. Visibility is 6,000 yards. The destroyer bears 300 degrees at a range of 15,000 yards at 0115.
REQUIRED:

   (a) If both ships remain on their present course and speed, would an alert lookout be able to sight the enemy?
   (b) If so during what interval of time?
   ans. (a) Yes
   ans. (b) Between 0130 and 0137

   (b) Assuming no change in courses and speeds, and on the basis of your initial contact, what time would you lose the contact from your radar screen?
   ans. (a) 201 degrees-10 knots
   ans. (b) 0021

5. You have determined that a contact is on course 138 degrees at a speed of 17 knots. You are now approaching a point 60 degrees off the port how at a range of 5,000 yards in order to fire a 36-knot torpedo at the contact.
REQUIRED:

   (a) On what course should the torpedo be set?
   (b) How far will the torpedo run?
   ans. (a) 234 degrees
   ans. (b) 4,300 yards

6. You have found an enemy transport which is traveling on a course of 235 degrees at a speed of 14 knots. You wish to use a speed of 24 knots to maneuver into a position 70 degrees off the nearest bow at a range of 6,000 yards. At the time of the start of the maneuver the enemy bears 116 degrees, range 16,200 yards.
REQUIRED:

   (a) What course will you use?
   (b) What is the length of time of the run?
   ans. (a) 139 degrees
   ans. (b) 11 minutes

7. A convoy is traveling on a course of 255 degrees at a speed of 12 knots. You wish to take it under fire from a position broad on the beam, from a range of 10,000 yards. At present it bears 150 degrees, 18,000 yards.
REQUIRED:

4. Your ship is traveling at 16 knots. On a course 325 degrees with an escort 2,000 yards dead ahead. At midnight the escort picks up a contact at 291 degrees, 15,200 yards from him and reports it. Five minutes later you find the contact bears 283 degrees, 14,800 yards.
REQUIRED:

(a) What is the contact's course and speed?

(a) What is the slowest speed you can use in this maneuver?
(b) What speed would you use to maneuver if you chose a course of 170 degrees?
ans. (a) 10.2 knots ans.
ans. (b) 16.6 knots

8. You are stationed 060 degrees relative to the guide, at a range of 6,000 yards. Base course is 300 degrees, speed 11

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knots. An emergency turn 90 degrees to starboard is executed at 0315.
REQUIRED:

(a) If you use a speed of 20 knots, what course shall you take to return to your station?
(b) At what time will you arrive on station?
ans. (a) 103 degrees
ans. (h) 0328

9. You have a contact south of you on a course of 080 degrees at a speed of 14 knots. You wish to come to a point 5,000 yards from the enemy to fire a 27-knot torpedo so that it will have a 90 degree track angle when fired. What is the true bearing of that point?

ans. 017 degrees

10. You are stationed on a true bearing of 101 degrees, 3,000 yards from a guide on a course of 340 degrees, speed 10 knots. You are asked to patrol out on your bearing for one hour at 20 knots and then return to station.
REQUIRED:

(a) What will be your course out and in?
(b) If you start your patrol at 1400 when will you arrive back on station?
ans. (a) 075 degrees - 307 degrees
ans. (b) 1520

INTRODUCTION

Since you will he a member of the Combat Information Center team (abbreviated CIC), it is essential that you understand the objective and functions of this organization. Entire books have been written on CIC, but in this manual only a brief description of the objectives and functions of this "nerve center" will he given in order to help you to adjust yourself to the part you will play as a member of the CIC organization. This description is followed by typical layouts of different type ships such as, BB's, CV's, CL's, and DD's.

OBJECT OF COMBAT INFORMATION CENTER

The object of the Combat Information Center is to assist the command in planning a correct course of action, and to assist the command and armament control in the execution of that plan.

FUNCTIONS OF COMBAT INFORMATION CENTER

The Combat Information Center, is briefly. an agency for the collection, evaluation, and distribution of combat information, and for facilitating the use of that information. It is not something strange and complex, nor is it merely a radar plot or an antisubmarine plot under a new name. It provides, however, a marked clarification and simplification of work for the command.

The following paragraphs in this section show how complex a Captain's life formerly was, and how relatively simple it has now become. They give some idea of the vast number of items formerly referred only to the Captain, who had to weigh each detail of the data himself and decide whether to use it, discard it, or file it in the back of his mind for future use. They show that the Combat Information Center is now the agency whose primary function is to filter and evaluate nearly all of this material for him. The Captain receives the information he needs when he needs it; and he is free to concentrate on his decisions and carry the burden of command. He has, in addition, in the CIC, an organization to which he can delegate secondary decisions and control duties as the occasion may require.

For purposes of functional analysis, the Combat Information Center may be considered as divided into two sections, *evaluation* and *control*.

To aid in the realization of the surprising mass of information available, the following lists are included. Obviously, much of the data will still go directly to the Captain, but details of sifting and correlating all of it need no longer distract him.

(a) Position information:

1. Visual ranges and bearings. 2. Optical ranges and bearings.
3. Radar ranges and bearings.
4. Sound ranges and bearings.
5. Direction finder bearings.
6. Radar detection receiver bearings.
7. Fathometer depths.
8. SMSD indications.

To make full use of this information in the CIC, it is displayed graphically on the DRT, summary, and air plots.

RADAR OPERATOR'S MANUAL

(b) Identify information:

1. Visual identification.
2. Radar identification (IFF).
3. Signal identification.
4. Underwater sound signal identification.
5. Maneuver identification.

At first thought, this identification may seem rather out of place in CIC. But the plot can show more readily than any other way, for instance, whether a plane sighted and reported by a lookout has previously been detected and identified by radar. It can show me easily if the maneuvers of an otherwise unidentified ship or plane are hostile.

(c) Reports from outside the ship:

1. Own forces' position reports.
2. Own movement reports.
3. Enemy contact, position, and movement reports.
4. Reconnaissance reports, positive or negative.
5. Intelligence reports.

These reports are filtered and sifted in CIC and the Captain receives, not a series of disconnected facts, but an evaluated report fitted into the entire tactical or strategical picture in its proper perspective.

(d) The background data (a partial listing, for illustrative purposes only):

1. Own ships' characteristics.
2. Friendly ship and plane characteristics.
3. Enemy ship and plane characteristics.
4. Own orders, plans, and objectives.
5. Assumed enemy plans and objectives.
6. Enemy habits and past performances.
7. Navigational information.
8. Geographical information.
9. Weather information.
10. Underwater sound condition data.
11. Own and enemy frequency plans.

To indicate the increased effectiveness of a ship, where all this information is available in one place and is sifted with greater thoroughness than the Captain has normally been able to do it, a hypothetical example is given: A destroyer is escorting a seaplane tender, and aircraft patrols have reported an enemy destroyer of Togo class on a course such that she will intercept during the night. The CIC can determine that the enemy carries a few small guns, but has many torpedoes. Intelligence reports indicate effective enemy gun and torpedo ranges. Knowing this, the Captain can plan how best to keep the enemy

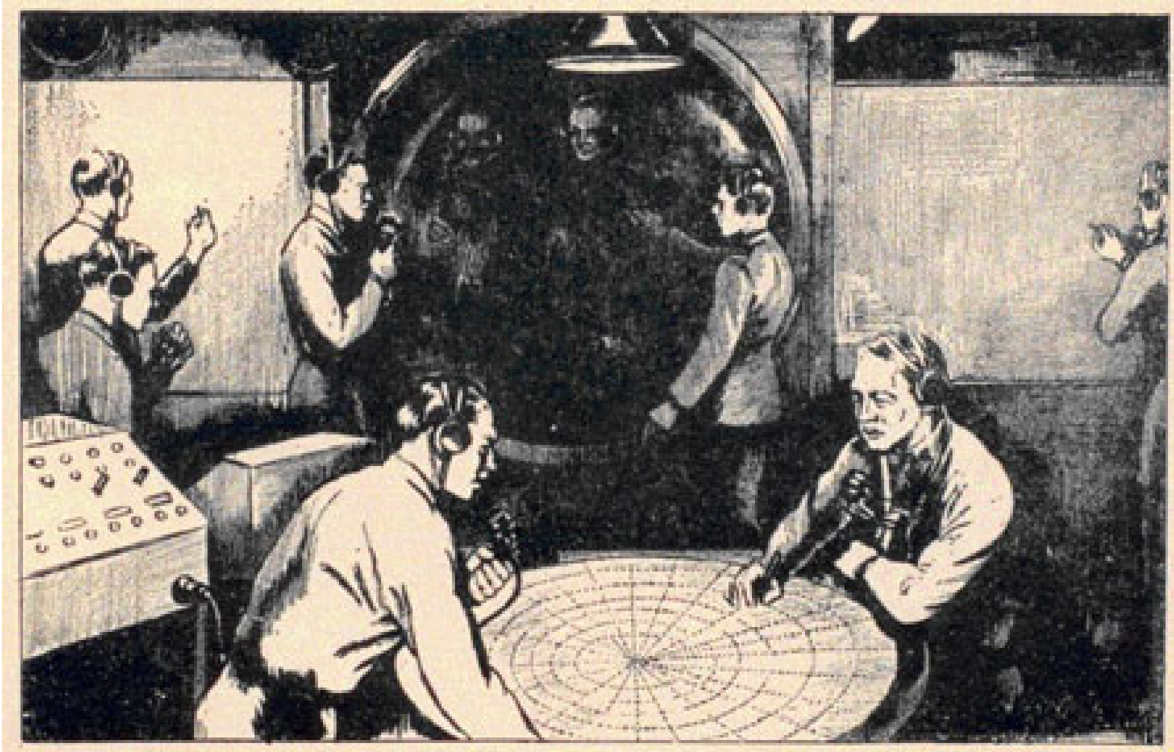

Figure 5-15. Information center at work.

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outside his effective torpedo firing range. He can anticipate under what conditions his own guns are most effective and the enemy's least effective. He can decide by comparison of speeds whether pursuit is advantageous, and he can plan his use of clouds and weather fronts for evasion if that action is advisable.

CIC is the source to which the Captain turns for a specific tactical or operational fact, for a general summary, or for an opinion or suggestion. The CIC through the evaluator, should provide the Captain with the following data:

(a) Filtered contact, position and identify information presented, according to the Captain's requirements at the time.

(b) Tactical and strategical summaries, which include facts necessary for the Captain's

data in torpedo fire, or actually select torpedo course.

5. Control, designate, or warn automatic weapons in fire against planes and torpedo boats.

6. Aid in delivering repeated anti-submarine attacks.

7. Control laying of smoke screen with respect to relative positions of own and enemy forces.

(b) With respect to the coordination with, or control of other units, the CIC can:

information and decisions, but which omit all irrelevant material.

(c) Pertinent reports and background data which contribute to his understanding of the problem at hand, and to the resultant decisions.

(d) Evaluated comment, suggestions, and opinions, based upon the greater availability of information in the CIC.

The control function of the CIC, with its detecting, tracking, and communication equipment, can be of inestimable assistance in matters concerning both own armament and coordination with other units.

(a) With respect to coordination with, or control of own armament, the CIC can:

1. Designate or suggest gun and torpedo targets.
2. Coach gun control on to targets.
3. Provide initial solution for gun computers.
4. Provide either point of aim and target

1. Control the details of radio communications, particularly voice radio, with other units in tactical company, thus relieving the Captain of this burden. This includes use of such codes as enciphered *General Signals* and the *TBS* and *Fighter* codes.
2. When own ship is senior, provide assistance in directing tactical movements of other ships in company.
3. Provide fighter direction, designation of target for strafing and bombing of shore objectives, or homing for aircraft.
4. Control movements of small craft, such as torpedo boats, landing craft; and small minesweepers or minelayers.
5. Participate in coordinated radar, sound search and tracking.

TYPICAL COMBAT INFORMATION CENTER

The Combat Information Center will he somewhat alike on all combatant ships, but will differ as to size, number of pieces of radar equipment, and personnel allowance, depending on the ship type. Some typical CIC layouts for BB's, CV's, CL's and DD's are illustrated on the following pages.

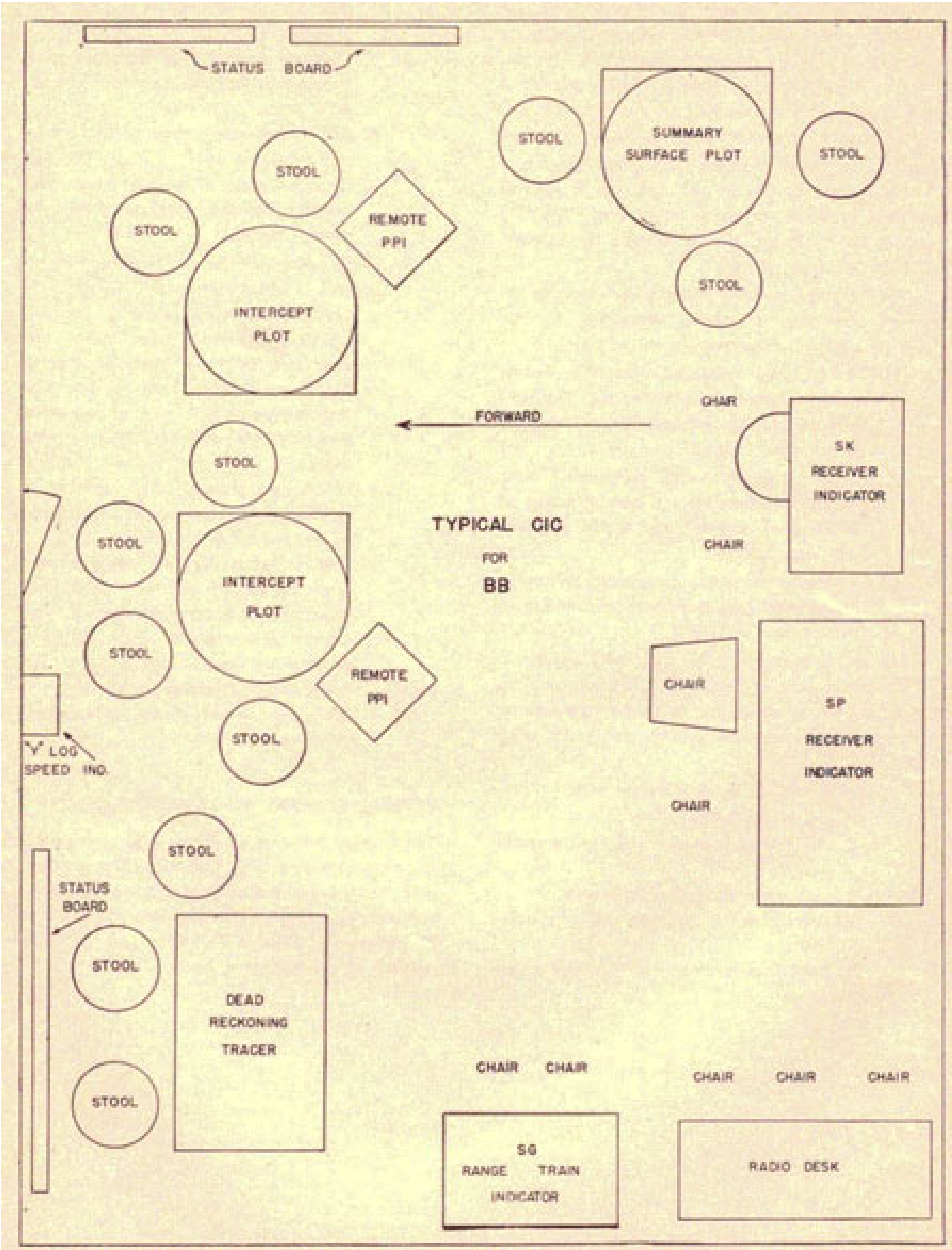

Figure 5-16.

COMBAT INFORMATION CENTER

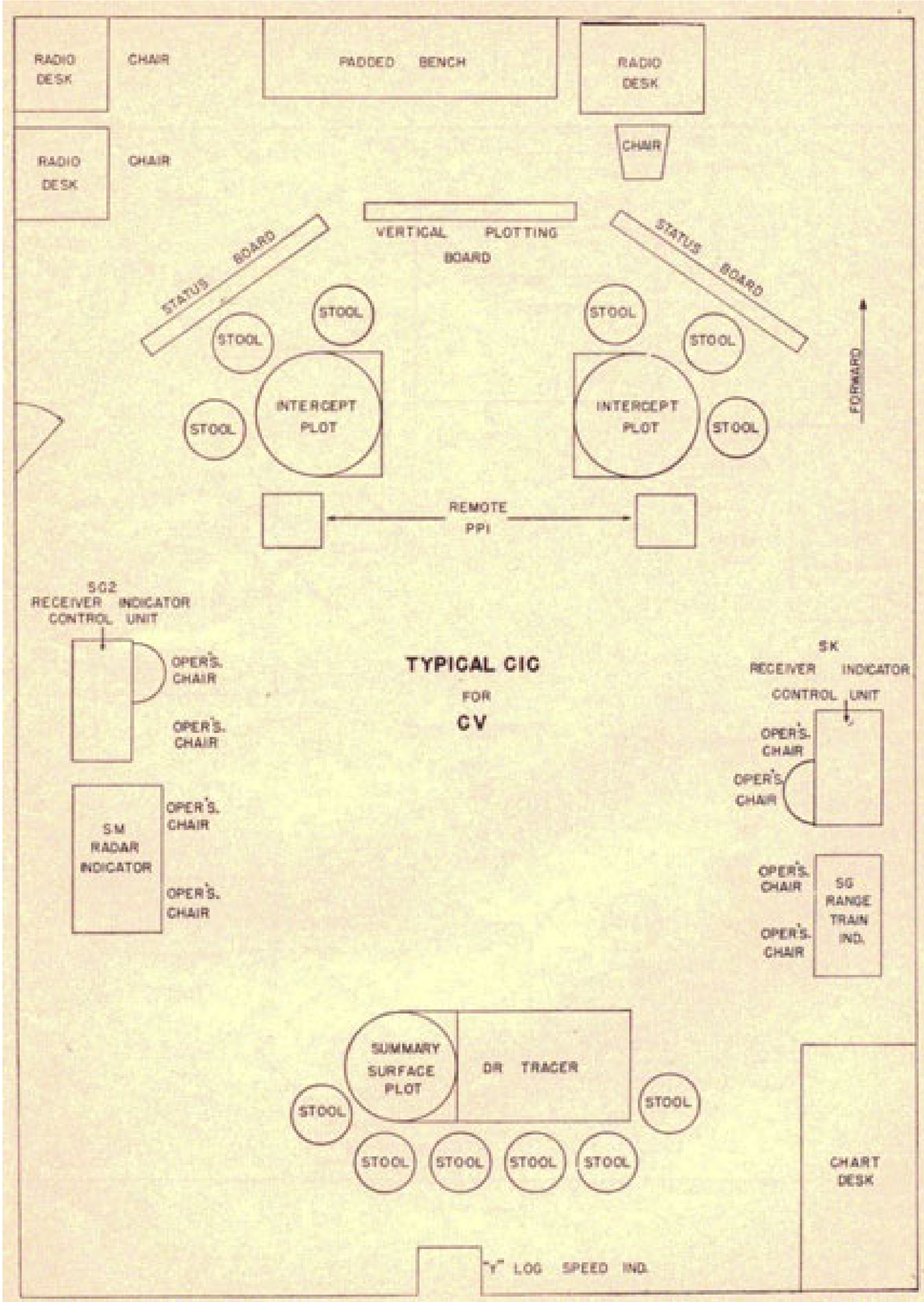
RADIO DESK
CHAIR
PADDED BENCH
RADIO DESK
RADIO DESK
CHAIR
CHAIR
VERTICAL PLOTTING BOARD
STATUS BOARD
STATUS BOARD
STOOL
STOOL
STOOL
STOOL
INTERCEPT PLOT
STOOL
STOOL
INTERCEPT PLOT
STOOL
FORWARD
REMOTE PPI
SG2
RECEIVER CONTROL
INDICATOR UNIT
OPER'S. CHAIR
OPER'S. CHAIR
TYPICAL CIC
FOR
CV
SK
RECEIVER CONTROL
INDICATOR UNIT
OPER'S. CHAIR
OPER'S. CHAIR
SM RADAR INDICATOR
OPER'S. CHAIR
OPER'S. CHAIR
OPER'S. CHAIR
OPER'S. CHAIR
SG RANGE TRAIN IND.
SUMMARY SURFACE PLOT
DR TRACER
STOOL
STOOL
STOOL
STOOL
STOOL
STOOL
CHART DESK
"Y" LOG SPEED IND.

Figure 5-17.

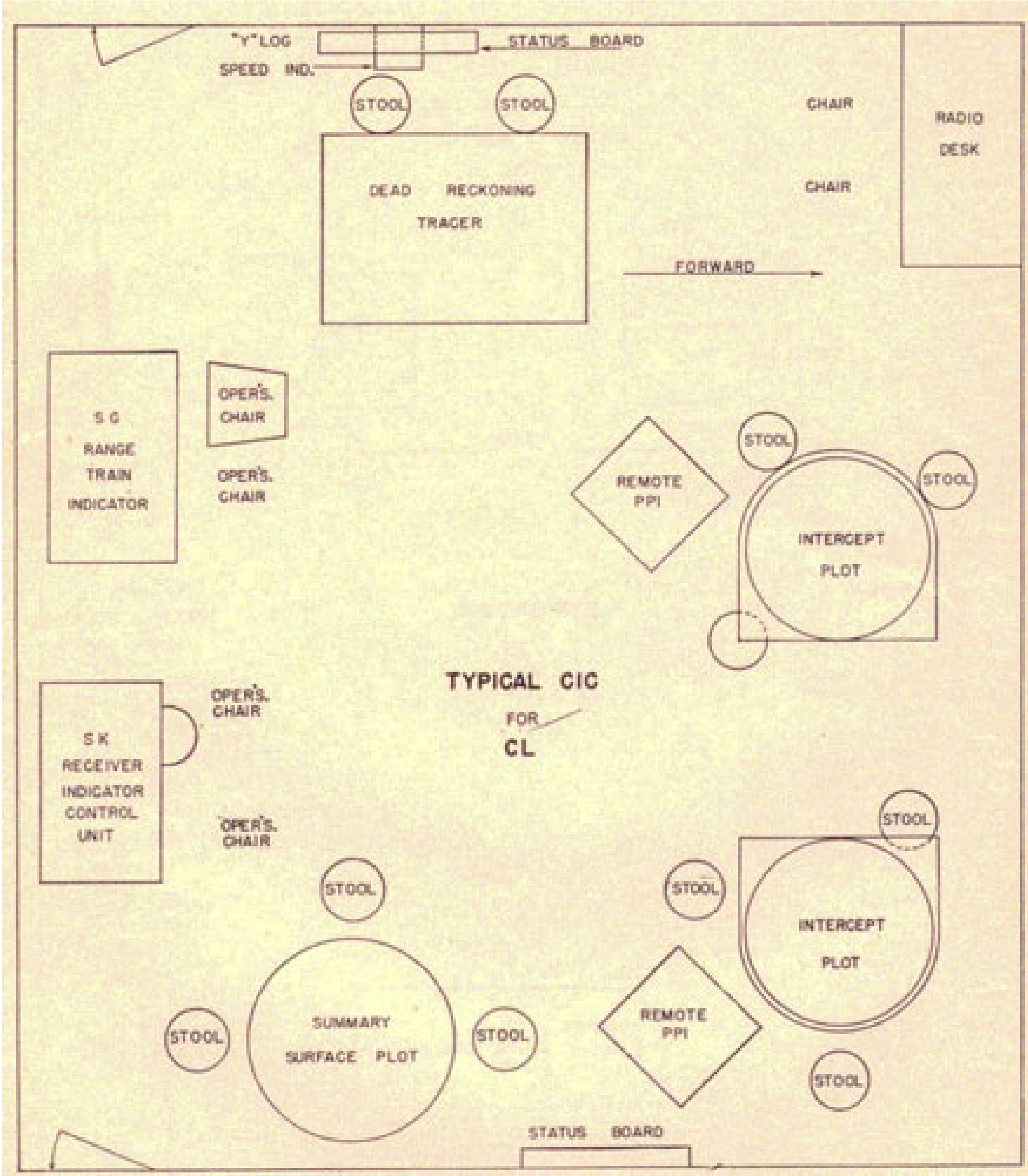

Figure 5-18.

COMBAT INFORMATION CENTER

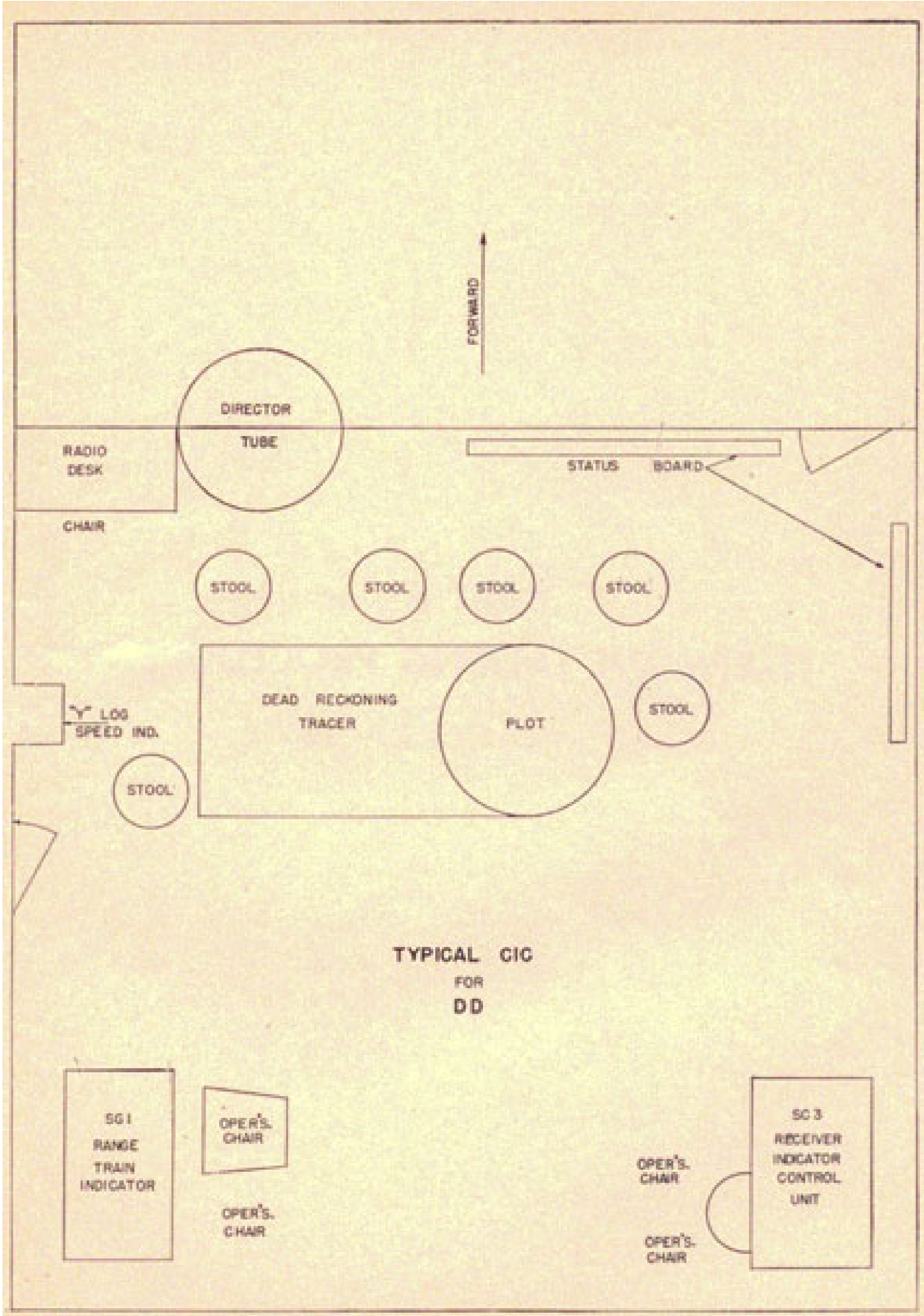
FORWARD
DIRECTOR
TUBE
RADIO
DESK
CHAIR
STATUS BOARD
STOOL
STOOL
STOOL
STOOL
DEAD RECKONING
TRACER
PLOT
STOOL
"Y" LOG
SPEED IND.
STOOL
TYPICAL CIC
FOR
DD
SG I
RANGE
TRAIN
INDICATOR
OPER'S.
CHAIR
OPER'S.
CHAIR
OPER'S.
CHAIR
OPER'S.
CHAIR
SC 3
RECEIVER
INDICATOR
CONTROL
UNIT

Figure 5-19.

Previous Part Radar Home Page Next Part

Version 1.00, 4 Sep 05

PART 6

TELEPHONE TALKING PROCEDURE

RADAR OPERATOR'S MANUAL

TELEPHONE TALKING PROCEDURE

INTRODUCTION

The success or failure of military operations, depend in a large measure on the right message reaching the right place at the right time. Upon the talkers rests much of the success of the Naval operations involving your ship. The information you glean from the radar screen is of little value unless it can be passed rapidly on to those responsible for the offensive and defensive tactics of your ship. For this purpose, *communication* means, *getting the informative messages through to the officers and men who are concerned*. A perfect system of communications is as essential to maximum radar protection as is good operation of the radar itself. You will be concerned primarily with the IC, or Interior Communications, i.e., the communications between various stations within the ship, rather than with communication with other ships, planes, or shore stations.

The Interior Communications system is important, since it makes it possible for an officer in one part of the ship to know what is happening in other parts of the ship. The Captain must be able to communicate with the control stations throughout

In nearly every case, information of this kind is sent from one station to another by means of sound-powered phones. We refer to the sound-powered phones, as the battle phones.

TELEPHONE CIRCUITS

Sound-powered telephones are linked together to form circuits; each circuit has a name. Circuits are labelled with letters and sometimes with numbers followed by letters. Each jack-box (the plug-in point for phones) on a circuit has a number. Main circuits are lettered from JA to JZ.

The main circuits which concern radar operators are:

21J5, 22JS, etc.
31J5, 32JS, etc.
41J5, 42J5, etc.

The use of these circuits on various types of ships is given in the table below.

When not operating the radar, you may be called upon to man one of the other phone circuits in CIC.

the ship, so that he ma get, swiftly and accurately, all the information he needs to make a vital decision instantly. The Gunnery Officer must be able to pass information to his gun crews, so that the guns can be properly controlled. The Engineering Officer must be informed immediately of damage or failure of the engineering equipment, The Officer of the Deck must he able to inform the Combat Information Center at once when an important message is received from another ship. The radar operator must be able to report to the plotter in CIC the up-to-the-minute status of the radar contacts.

The JA circuit is the Captain's battle circuit. It connects Conn (the Captain's battle station) with control stations throughout the ship, this is the main fighting circuit of the ship. Over this circuit the Captain gives orders to his officers at control stations, receives reports from them regarding the progress of the action, casualties to material and personnel, and damage to the enemy.

The 1JV circuit is the primary maneuvering circuit. This means, that messages concerning the speed and course of the ship. mooring and anchoring lines, are sent over this circuit. Information on this circuit helps

Type of ship	*21JS, 22JS, etc.*	*31JS and 32JS*	*41JS, 42JS, etc.*
BB, CB, CA, and CL	Ship control (detector) radar No. 1, No. 2, etc.	Main battery radar No. 1, No. 2.	Secondary battery radar No. 1, No. 2, etc. Fire control radar No. 1, No. 2, etc.
DD	Ship control radars (search radar) No. 1, No. 2, etc.		
DE	Ship control radars (search radar) No. I, No. 2, etc.		

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to get the ship in and out of port, and to maneuver when at sea. It connects Conn with such places as the engine rooms, fantail, and forecastle.

The following is a list of the phone circuits and the main functions of each:

Circuit	*Designation*
JA	Captain's battle circuit (on vessels where circuit JL is not installed, this circuit is designated, Captain's battle and lookout circuit).
JB	Main battery spotters.
JC	Main battery control.
JNT	Illumination control.
JP	Secondary battery units.
5 JP	Secondary battery control.
JS	Radio and sound bearing circuit.
1 JS	Combined radar-radio information circuit.
51 JS	Radio direction-finder circuit.
JSV	Sound and maneuvering control.
JT	Searchlight control.
JU	Torpedo, depth charge, and smoke control.
1 JU	Torpedo control.
1 JV	Maneuvering, docking, and catapult control.
5 JV	Engineer's circuit (electrical).

JD	Main Battery units.
2 JD	Forward main battery control.
JF	Flag circuit.
JL	Lookouts.
JN	Illumination control (starshell).

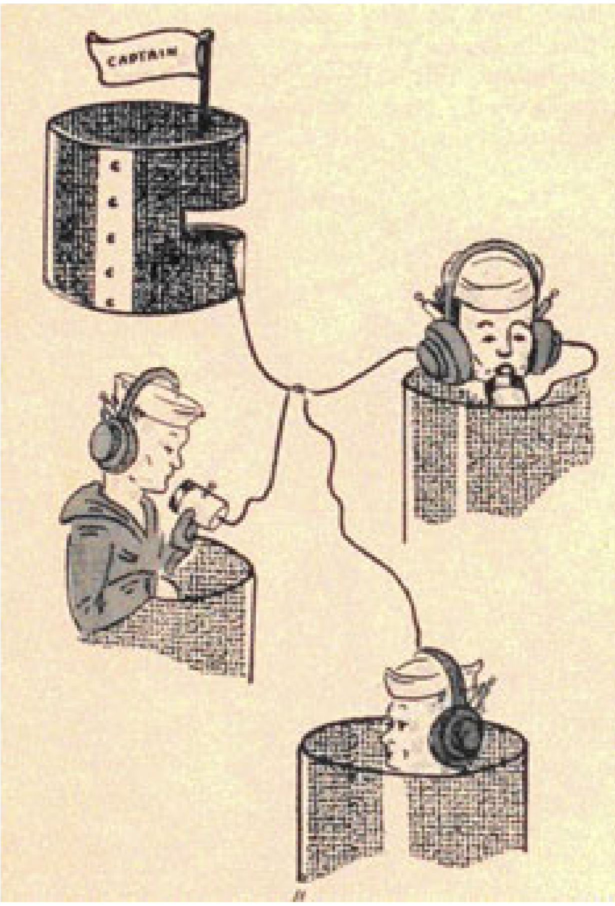

Figure 6-1. The JA circuit connects the Captain's battle station with control stations throughout the ship.

JW	Rangefinders circuits.
JX	Radio and signals.
1 JX	Visual signal circuit.
2 JX	Radio signal circuit.
JY	Machine gun control and battery.
2 JZ	Damage control circuit.

See your ship's organization bill for specific information on the phone circuits in use in your CIC. Learn the primary purpose of the various circuits, and know every station on those you may be called upon to man.

All primary circuits, except those listed below, have auxiliary circuits: JF, JH, JN, JO, JR. JS, JSV, and JU. The letter *X* precedes-the designating letters: i. e., auxiliary Captains circuit, XJA. You might think of the X as standing for an extra circuit. These *X* circuits will serve all, or most of the stations served by the primary circuit. They are designed to he used in an emergency, or for use as an auxiliary means of communication when needed. Although the *X* circuits are independent from the primary circuits, they may become a part of the primary circuit by means of a central switchboard.

In addition to the sound-powered phone circuits, an intercom system, comprising the MC circuits, carries an important share of the interior communications load. It is a speaker type telephone designed to provide amplified voice intercommunication between any two or more circuits. General announcements, commands, and filtered information are handled by the numerous MC circuits.

These are some of the MC circuits with which you are most likely to be concerned:

1 MC	General announcing system.
20 MC	Radar control announcing system.

21 MC Captain's command announcing system.

22 MC Radio room announcing system.

24 MC Flag officer's command announcing system.

TYPES OF SOUND-POWERED PHONES

Sound-powered telephones must always he kept in good condition, ready for any emergency. There are delicate parts in the phones, therefore, it is important that you learn how to handle them properly, how to wear them correctly, and how to take care of them when they are not in use.

There are two types of sound-powered phone sets: the handset and the headset, which can be used simultaneously.

Handset.

The *handset* telephone looks very much like the cradle (or French type) telephone used in many offices and homes. It is held in one hand and when the earpiece is placed against the ear, the transmitter (or mouthpiece) comes directly in front of the mouth. On the bar connecting the receiver and the transmitter there is a push-button. This button must be held down whenever you are speaking or listening. This rule applies to the handset type of phone only. When someone is calling your station you will hear the call buzzer. When you wish to talk with another station, you must press the buzzer button to get the attention of that station.

When the handset telephone is not in use, it is held in a bracket on the bulkhead. This bracket has a clamp that keeps the phone firmly in place. Be sure to secure the phone correctly when you are through talking. If it should fall to the deck it wires go to the earpieces. Then there is one long, heavy cord called the *lead*, at the end of which there is a heavy metal plug. The plug fits into a jack-box on the bulkhead which connects the phone to the rest of the circuit. The plug is usually held in place by means of a collar with screw threads on the inside.

On the jack-box there is a small disc of paint that shines in the dark so that you may find it easily. Also on the jack-box are letters which identify the circuit. In some eases there will also be a selector switch, located near the jack-box, so that an authorized person may switch from one circuit to another without removing the plug.

WEARING THE PHONES

Since the headset as well as the handset is made of delicate parts, it is important to know how to wear them. When you put on the headset telephone, hold the transmitter unit and the heavy lead in the left hand. Hook the metal headband over the transmitter yoke, in the space between the mouthpiece and the breastplate. This will keep the earphones from being dropped. Next, unhook the tight side of the neck strap from the breastplate, put the strap around

would he seriously damaged.

The handset phone, although convenient, has certain disadvantages. Therefore, it is used only as a service phone between such places as officers' rooms. bridge, and ward room, or in cases of emergency if the headset phones should fail to work.

Headset.

The headset telephone, since it is the equipment you will most frequently use, it will be explained in detail

The *headset* telephone consists of a pair of earphones and a transmitter. The earphones are on a spring metal clamp or fabric harness that fits over the talker's head. The transmitter (or mouthpiece) held in an adjustable yoke, or (Y) pin, is mounted on a breastplate. The breastplate is held in place by a strap around the talker's neck. Also on the breastplate, is a small box where the wires are joined together. One of these wires is short and extremely fine, and goes to the mouthpiece. Two other fine

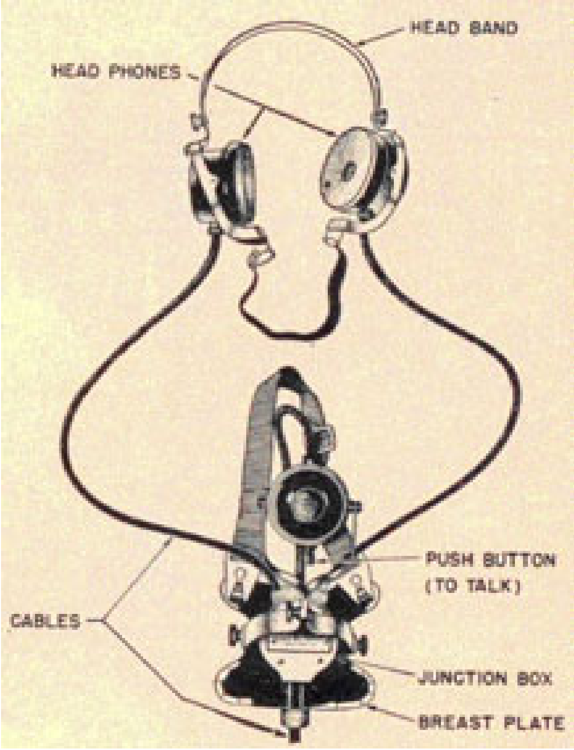

Figure 6-2. The headset.

TELEPHONE TALKING PROCEDURE

your neck, then fasten it to the breastplate again. Now put the earphones on and adjust the headband so that the center earpiece is directly over the opening into the ear. Insert the plug into the jack-box, and while holding the plug with one hand, screw the collar on firmly, taking care not to cross-thread the plug collar.

If these directions are followed, no portion of the equipment will hang by the cords. If equipment is allowed to dangle by the cords the electrical connections will soon he broken.

the earphones you can hold the transmitter button down and receive as well as send a message with the transmitter. This is a good thing to remember in an emergency, when a break in communication might mean disaster.

In wearing the phones you should make the following adjustments:

Adjust the earpieces so that the center of each earphone is over the opening into the ear, with the headband fitting firmly over the top of the head.

A talker should never torn one earpiece outward from the head. When this is done, outside noise is picked up and carried into the circuit, making it difficult for other talkers to hear. In such places as the engine room, boiler room, and gun turrets, there may be so much noise that the entire circuit will become useless, all because one talker has an earpiece turned outward.

The fact that noise can he picked up and carried into the circuit by the earpieces shows that they work just like the transmitter. The outside of the earpieces are a different shape from the outside of the transmitter, so that they will fit your ears. On the inside, however, transmitter and earpieces are the same. This is an important fact to remember.

In case of a casualty to the transmitter on a headset phone, you can speak into one ear piece while listening through the other; in case of a casualty to

Figure 6-3. In case of casually to the transmitter, speak into one earpiece and listen through the other.

Adjust the mouthpiece so that it is directly in front of your mouth when you stand erect. When you speak into the transmitter it should be not more than one-half inch from the mouth. In making this adjustment remember that the fine wire that goes to the transmitter can easily he broken. Be sure that there are no sharp bends in it and do not allow it to get caught between the transmitter and the yoke. An electrician's mate on any ship will tell you that he has several phones to repair every day just because talkers are careless in handling the phones.

When you are wearing the phones remember that you cannot walk any farther than the length of the lead cord. If you do, you may break the connection at the plug. Therefore, always keep some slack in the lead and he sure it is flat on the deck so that no one will trip over it. Do not allow objects to roll over the lead.

Before plugging into the jack-box, give your phones the blow test. Hold the transmitter button down and blow into the mouthpiece. If you do not hear a "sh-h-h" sound you know your phones are not working. If the phones are not in order take them to the titan in charge of your station. If that is not possible, another talker near you can report the matter to the control station. Phones that are out of order may prevent other phones on the circuit from working properly. Never stow a damaged phone: see that it is taken immediately to the electrician's mate for repairs, for you never know when an emergency may arise which will require the use of every phone on the ship.

As soon as you are sure the phones are working properly, put the plug in the jack-box. See that the collar is screwed firmly in place. To do this, hold the plug in one hand and turn the collar with the other. If you do not hold the plug while you screw on the collar, the wires will twist and may weaken the connection in the plug.

When the plug is securely connected into the jackbox you are ready to listen. If you have a message

to send to someone else on the circuit, push down the button which is on the top of the transmitter. This button should be held down only during the time you are speaking, and should be held down until you have delivered the whole message. It should not be held down at any other time.

Note that this procedure differs from that used with the handset phone. With the headset phone you push the button only when speaking. With the handset phone the button is held down when you are speaking and listening.

It is exceedingly bad practice to keep the button taped down, or held down by a rubber band, because this practice makes it possible for outside noise to get into the circuit. Phonograph recordings made on the telephone circuits on board ship show that when this is done it is very difficult for anyone on the circuit to hear a message. Consequently, do not tape the button down unless you are ordered to do so.

When exposed to the wind, keep the mouthpiece shielded with your hand while talking, otherwise the wind will produce noise in the phone.

All the power required to operate sound-powered telephones is generated by your voice; no other source of power is needed. Therefore, if your message is to get through, you must speak loudly and cleans. Your voice must supply enough power so that as many as 20 other men on the circuit can hear you. In plain words, weak voice, little power; strong voice, lots of power. Regardless of how clearly you speak, if your voice lacks power the

Studies on the functioning of the phone under conditions of excessive noise show that it is important to speak with a *loud, clear voice*. These studies also show that it is important *to have the month close to the transmitter*. If the mouth is one-half inch from the transmitter, all messages will get through provided the phones are working properly. If it is two inches away, only two-thirds of the messages will get through. At a distance of four inches, less than half the messages will be correctly heard, and at tight inches only one message in five will be heard correctly by the listener.

With these facts in mind, carefully study the following section.

HOW TO SPEAK OVER SOUND-POWERED PHONES

Talk in a loud voice and maintain it consistently, so that every word will get through to every other man on the circuit. Few men will talk too loudly.

Hold the transmitter *not more than one-half inch from your mouth* when talking in a noisy place.

message will not get through.

Figure 6-4. Very few men will talk too loudly.

Figure 6-5. Watch the lip and mouth movements of a good speaker, and you will see what is meant by articulation.

Articulate clearly.

Articulation means moving the lips and the tongue so that each sound is made correctly and clearly. For example, when you say "oh" your lips should be definitely rounded. An "ee" will be clearer if the lips are pulled back at the corners. Make every part of the message stand out so that even unfamiliar words may be understood by the listener. For example, the sentence, "prepare to stream paravanes," may be unfamiliar to the listener. So say, "pre-*pare* to stream par-a-*vanes*." The italicized sounds are those often slighted, so make them especially clear.

Watch the lip and mouth movements of a good speaker and you will see what is meant by articulation. Never speak with gum or food in your mouth when on the phones. Talk from the front of your mouth, never from the corners. Imagine that you must *project* your voice to everybody on the circuit.

Talk slowly.

There is nothing to be gained by talking rapidly just to see if another man on the circuit can numbers he understood at all times, since they provide such important information as the bearing and range of other ships and planes, the number of contacts, the elevation of aircraft, and so on.

Careful study of the pronunciation of numerals indicates that the following exaggerated pronunciations are highly recommended:

understand you. A slowly spoken message that is understood the first time will be much quicker than a rapidly spoken message that must be repeated.

Excitement is the greatest cause of speaking too rapidly. Doting a crisis, remember, that it is doubly important to get the message through. *Talk slowly* and some of your own excitement will subside. If you are calm and sure of yourself, you will influence other men on the circuit to behave the same way.

Restrict your dialect or accent.

Each one of us has a manner of speech which tells others what part of the country we are from. You may have on occasion found it difficult to understand a man from another section of the country. With this in mind, try to speak in such a way that your listeners cannot tell whether you come from New England, the Deep South or the West. Numbers are especially difficult to understand if you fail to restrict your dialect or accent. It is important that

Figure 6-6. Restrict your accent or dialect.

One - Wun	Six - Sicks
Two - Too	Seven - Seven
Three - *Thuh-ree*	Eight - *Ate*
Four - Four	Nine - *Niner*
Five - *Fiive*	Zero - *Ze-ro* (designated "oh" for range)

The italicized numbers are often confused. Repeat all the numbers aloud, taking particular care with those in italics. Try' to speak so that anyone from any part of the country can understood you. Numbers should be spoken with each individual digit pronounced. For example, 5980 is spoken fiive-niner-ate-oh."

Standard Navy phonetic alphabet.

Another aid to a clearer understanding of messages is the Standard Navy Phonetic Alphabet. In your messages, letters will not be spoken as letters, but will be referred to by their assigned names. The sounds "bee," "dee," "cee," "gee," "tee," are easily confused; so are "aitch," "A", and jay". But if you use the names for these letters, Baker, Dog, Charlie, George, Tare, How, Able, and Jig, there will be no confusion. The phonetic alphabet is given below:

Letters	*Spoke as*	*Letters*	*Spoken as*
A	ABLE	N	NAN
B	BAKER	O	OBOE
C	CHARLIE	P	PETER
D	DOG	Q	QUEEN
E	EASY	R	ROGER
F	FOX	S	SUGAR
G	GEORGE	T	TARE
H	HOW	U	UNCLE
I	ITEM	V	VICTOR
J	JIG	W	WILLIAM
K	KING	X	X-RAY

L	LOVE	Y	YOKE
M	MIKE	Z	ZEBRA

Memorize the alphabet thoroughly so that you can use it quickly and accurately as in JA, "Jig Able":

IJV, "One Jig Victor; Compartment A-307-L, Compartment Able Three Zero Seven Love.

The phonetic alphabet is easy to learn if you will practice spelling out names and words that come to your mind, for example JIG OBOE HOW NAN SUGAR MIKE ITEM TARE HOW spells John Smith. TARE OBOE NAN YOKE spells Tony.

Figure 6-7. Practice spelling names and words.

STANDARD PROCEDURE AND STANDARD TERMINOLOGY

Giving a message.

Most messages are divided into three parts:

aye, mean, "I understand your message or order and will carry it out to the best of my ability." A message has been correctly acknowledged when the talker has identified his own station and followed with, "aye aye." When acknowledgments are made in this way the sender knows that you, not someone else, have received and understood the message, or that you will carry out the order. For example, always say, "Sugar Charlie, aye, aye," not just "aye, aye."

Repeating back.

When a message is important the radar operator (talker) originating it may want to make sure that it has been transmitted and received correctly. In this case he will tell the receiving station to repeat it back.

Requesting repeats.

When a message is not clear to the listener at the receiving end, he should say, *repeat*. The query. "what did you say?" should never be used as it requires too much time. Be sure that you repeat the message word for word; changing the wording causes endless confusion.

Brevity.

To make communications rapid, messages must be kept short. This is a matter which primarily concerns tile radar operator originating the message. Plotters

1. Name of the station being called.
2. Name of the station calling. (On certain command circuits, step 2 is omitted at the discretion of the commanding officer.)
3. The message itself.

Note very carefully the above order. First you call the station for which the message is intended, then you identify your own station, and finally you state the message. To change this order is dangerous because confusion may result.

Acknowledging.

When a message is received it must be acknowledged at once if it is understood. The words, *aye*

should also keep the principle of brevity in mind as they may originate messages themselves. All unnecessary words should be omitted. Words like *please* and *sir* are omitted on the phones in order to keep messages short. If a message must be long it should be grouped into phrases to make it clear.

Figure 6-8. Do it the Navy way.

Silence on the line.

When a circuit is in use, but the control station has a more important message to get through, the control talker says, "*silence on the line*."

Whenever this is heard, you must stop talking so that control can get the message through.

Circuit test.

As soon as the phones are manned, the CIC station must know when all the other stations are ready. To do this, the talker at combat says, "*All stations, combat, testing*."

Each talker on the line then acknowledges in the order designated by the controlling station. On a radar circuit the acknowledgments should sound like this:

always follow the designation of the contact (designations will be the same as those used in the Fighter Director Code listed in RADFIVE) as bogey, friendly, etc., and it will be in three digits, for example: 005 degrees will be, *zero zero five*: 060 degrees, *zero, six zero*: 280 degrees, *too eight zero*. Likewise, when reporting the range, the third part of the report on any contact, leave out the word "range"; it will always be understood that the numerical data following the bearing will be the range of the target. Whether the range is measured in yards or miles, omit the word yards or miles from the report. Merely say for 15,800 yards, "*One five eight double oh*" not "*one five eight double oh yards*." The plotter will understand that the range must be in yards sine no radar set has such a fantastic range as 15,800 miles. If the target's range is 45 miles, just say "*forty five*." The plotter will realize that the figure must be in miles. No radar set can pick up targets at 45 yards.

Talker on Sugar George: "Sugar George, aye aye."
Talker on Sugar Charlie: "Sugar Charlie, aye aye."
Talker on Sugar Mike: "Sugar Mike, aye aye."

A circuit test is not complete until every man has answered, and faults in the equipment are checked.

Order of reporting air contact information.

Terminology as well as procedure must be standardized to avoid confusion during concentrated attacks. The following notes will provide a basis for such reports:

1. Bogey or friendly: raid designation, I, II, III, etc. (Roman numerals only if directed by CIC officer.)

2. Bearing: true, unless relative has been specified.

3. Range: miles.

4. Number of planes.

5. Appearance of the pip: large, fluctuating wide base, etc.

6. Altitude: if SP or SM radar.

7. Amplifying information: opening, orbiting, closing, crossing.

Standard terminology in reports.

When reporting the *bearing* of the target, it is standard practice to call the cipher *zero*. When reporting a bogey, the operator should furnish the information concerning the first contact of an unidentified group as quickly as possible. In the initial report the operator should determine as soon as possible whether the contact is a large or small group, the approximate bearing, the range, and whether the formation is opening, closing, or crossing. The second and subsequent reports should eliminate the approximation of the bearing and such words as small, large, closing, etc., unless there is additional data or a change in previously furnished information. They should also furnish a more accurate bearing, the up-to-the-minute rang; and the estimated number and type of aircraft.

Let us listen in on the 22JS circuit:

"Combat, Sugar Charlie; large bogey, zero seven five, sixty-four, closing." (Example of first report.)

"Combat, aye, aye." (Combat can drop "Sugar Charlie in direct established communication when no error can be made.)

"Combat, Sugar Charlie; large bogey, zero six eight, sixty-one, about thirty planes."

"Combat, aye, aye." (in the meantime the FDO may have designated the raid as "Raid I"). "Report large bogey as Raid I."

"Combat, Sugar Charlie, aye, aye."

Reporting surface contact information.

1. Surface contact: raid designation is so ordered.

2. Bearing: true, unless relative has been specified.

3. Range: yards.

reporting the *range* of the target, it is proper to call the cipher *oh*. As indicated by the above list, the correct order for reporting, calls for the bearing as the second part of the message. The word "bearing" is not used in the report. Instead of "bearing, one two zero," merely say, "One two zero." There will he no reason for confusion since the bearing will

4. Number of targets.

5. Type of echo: large steady pip, small bobbing pip.

6. Amplifying data: large ship, small ship.

In reporting surface contacts and raids by surface craft, the same rules apply in-so-far as standard terminology and arrangement of information in the message is concerned.

Let us listen in on a 21JS circuit:

> "Combat, Sugar George; surface contact, one five zero, two niner oh double oh, single contact, small steady pip."
>
> "Combat aye, aye."
>
> "Combat, Sugar George; land, two niner one, six five oh double oh, strong steady pip."
>
> "Combat, repeat."
>
> "Combat, Sugar George; land, two niner one, six five oh double oh, strong steady pip."

Circuit discipline.

Standing a radar watch is not always exciting. You may sit with the phones on for some time without observing a contact on the radar screen, hence no important messages will be passed over the circuit. Under these circumstances, it is easy to become careless and take part in a private conversation with someone else on the line. Recordings made on board ship show that several talkers may take part in such a conversation and because of this unnecessary talking there is the danger of delay when an important message must go through.

You as a talker, are a link in the Interior Communications chain, and that chain is no stronger than its weakest link. *Unauthorized talking means that there are at least too week links in the chain*; be efficient. If someone else on your circuit persists in useless talking, remind him that the line must be kept clear so there will be no delay when a message must go through.

Circuit discipline means that the talker must never show impatience, anger, or excitement. He must talk slowly, in a loud, clear voice. Circuit discipline means self-discipline.

Do not use slang or profanity on the phones.

Never say, for example "Yeah"; say "aye aye." Use

"Combat, aye, aye."

Speed is essential; your attention is called to this report from the USS South Dakota: "Involved and slow communications . . . leave us at a tactical disadvantage." Every minute you lose in reporting enemy aircraft allows them to approach several miles closer. An airplane traveling only 300 miles an hour moves in on you at the rate of *five miles a minute*. This fact alone should make clear the necessity of keeping messages brief. Get off the line as quickly as possible so that others can report. There can be no, "Sorry, the line is busy."

Be accurate and precise, radar is accurate equipment. The enemy also has radar; that puts it pretty much up to you to be more accurate than the enemy.

Changing talkers.

The following procedure will he used when changing talkers at any radar station. When combat changes talkers, the old combat talker will say:

"Combat, shifting phones."

When phones are changed, the new combat talker will say:

correct nautical terms.

Navy language.

A good talker will do a better job if he knows what he is talking about. If you have a detailed knowledge of ship's terms you will be not only a better talker, but a more intelligent listener as well. You will know what is said because you will know what to expect. To properly report the contacts to the plotter you must know and use the common terms from the Fighter Director Code.

Dozens of examples could be given to illustrate how a talker, who does not know his ship, is a dangerous link in the communications chain. Ship's speech is made up of a number of new and unfamiliar terms.

A knowledge of such terms will help you as a talker and as a listener. You will find some of them in *The Bluejackets' Manual*; others will he learned from experience. Keep your eyes and ears open as you go about your ship. A familiar term will always be easier to understand and speak than a strange one.

SECURING THE PHONES

Before securing the phones, you must always get permission. The procedure would be:

"Combat, testing." To this radar stations will answer in order:

"Sugar Charlie, aye, aye."

"Sugar George, aye, aye."

"Sugar Mike, aye, aye," etc. Other radar stations report shifting phones with talker saying:

"Sugar Charlie, shifting phones."

When phones are changed, the new talker will say:

"Sugar Charlie, testing."

To which Combat will acknowledge the test by answering:

"Combat, aye, aye."

TELEPHONE TALKING PROCEDURE

Sugar Charlie asks:

"Combat, Sugar Charlie; may I secure?"

Combat says:

"Combat, aye, aye; wait."

Combat gets permission for Suger Charlie to secure, then:

"Sugar Charlie, Combat; you may secure."
"Sugar Charlie, aye aye; securing.

Never secure the phones until you have

permission to do so. When this permission has been given, you are ready to *make up* the phones. The phones will make up somewhat differently for various methods of stowage, but the following method will suit most conditions:

1. Remove the plug from the jack-box by holding the plug in one hand and unscrewing the collar with the other. When the collar is loose, grasp the plug and pull it out. Never pull it out by the lead as this will weaken the connection. When the plug is out, lay it on the deck being careful not to drop it.

2. Screw the cover on the jack-box. Always do this immediately. Rain, spray and dust will soon cause a short circuit in a jack-box that has been left uncovered. If you see a jack-box

Figure 6-9. Know your ship and her language.


Figure 6-10. Stow phones when they ore not being used.

that has been left uncovered, cover it even though you were not responsible for this careless act.

3. Remove the headband and hang it over the transmitter yoke.

4. Leave the plug lying on the deck, and coil the lead cord. Start coiling from the end near the phone, and leave the rest on the deck. Coil the lead in a clockwise direction and hold the loops in one hand. The loops should be eight to ten inches across, depending on the size of the space where the phones are to be stowed. When you are coiling the lead be careful not to bang the plug against the bulkhead or deck.

5. When the lead is coiled, remove the earpieces from the transmitter yoke, and place the headband in the same hand with the coil.

6. Use the same hand to hold the transmitter while you unhook one end of the neck strap from the chest plate.

---

7. Fold the transmitter yoke flat. Be very careful not to put a sharp bend in the transmitter cord when you do this.

8. Bring the back of the chest plate together with the headband and the coil. Secure in this position by winding the neck strap around the coil and the headband just enough times so that there will be a short end left over. Fasten this end back on the breastplate. You will then have a neat, compact package to be stowed.

9. Put the phones in the box provided. Be sure that all parts of the phones or cords are entirely inside the box. If the phones, or the inside of the box are wet, wipe them dry, for constant exposure to moisture will damage them. Close the box tightly so water and dust cannot get in. Below decks, hooks are provided so that phones may he hung up.

Remember that the phones must be unplugged no matter what method is used to secure them. Phones that are left plugged in, will pick up noise through the earpieces and carry it into the circuit. A most dangerous act is that of placing the phones on the deck. Besides the fact that someone may step on them, the deck will echo all the surrounding noise and cause it to go into the phones with great force.

SUMMARY

1. *Test* equipment as directed.

2. Keep the transmitter one-half inch from your

3. Talk in a loud, clear voice at all times. Suppress your accent.

4. Speak *slowly* and remain calm.

5. Repeat *exactly* the information given you to relay.

6. Hold the transmitter button down when speaking and *only* when speaking.

7. *Call* the station you wish to contact, next *identify* your own station, finally give your *message*. Example:
"Sugar King (call); combat (identification) ; report when manned and ready (message)."

8. Acknowledge all messages when they are understood. If you do not hear or understand a message, say only, "repeat."

9. Use the circuit only for *authorized* messages.

10. If the transmitter should go dead, talk through either earpiece.

11. Report faulty equipment at once.

12. Leave the phones *only* when you have permission to do so, as in changing phones or securing.

13. In securing, carefully coil the lead wire so that it is not kinked, fold the phone, hang the phone up, or stow it carefully in a closed box with tightened cover.

mouth, and the earpiece centered over your ears. *Avoid dangling leads* in placing and removing the phones.

14. Secure the jack-box firmly screwing on the watertight cover.

When you are a telephone talker you have an important job. You and your phones are the nerves of the ship. If a message is not understandable, or if it is incorrectly repeated, your ship may be placed in danger. In battle, the safety of the ship and crew depends upon how well you used your voice and equipment.

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Previous Part Radar Home Page

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PERU

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RUSSIA

Cruiser *Aurora*, St. Petersburg
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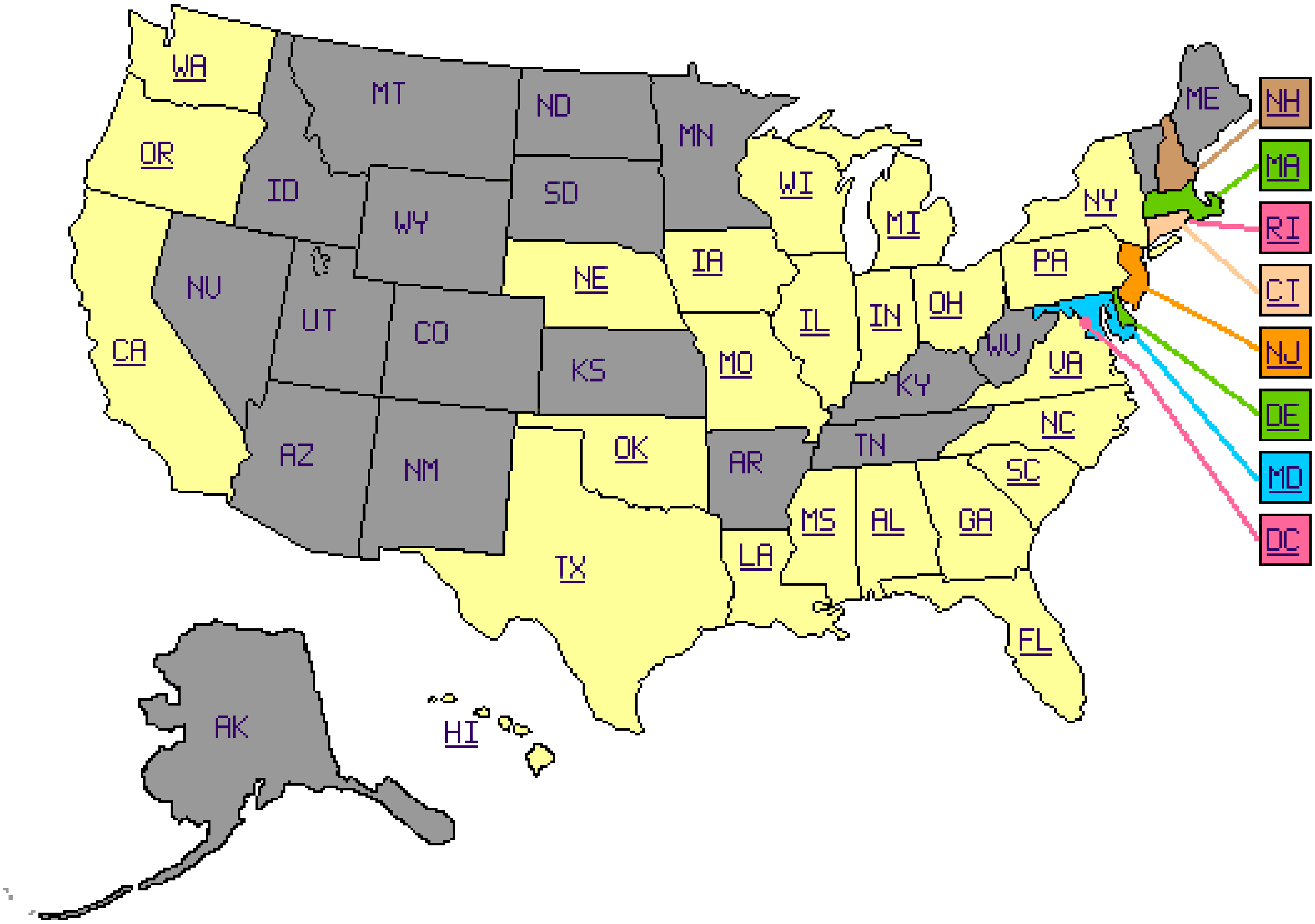

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PBR Mark II, Mobile, Alabama

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- Japanese *Kaiten*, Honolulu, Hawaii
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- German *U-505*, Chicago, Illinois

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- USS *LST-325*, Evansville, Indiana

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- USACOE Dredge *William M. Black*, Dubuque, Iowa

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- *LCM 56*, Fall River, Massachusetts
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- USS *Massachusetts*, Fall River, Massachusetts
- *PT 617*, Fall River, Massachusetts
- *PT 796*, Fall River, Massachusetts
- USS *Salem*, Quincy, Massachusetts
- German *Seehund*, Quincy, Massachusetts

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Fenian Ram, Paterson, New Jersey
Holland Boat #1, Paterson, New Jersey
Intelligent Whale, Sea Girt, New Jersey

New York

USS *Slater*, Albany, New York
USS *Croaker*, Buffalo, New York
USS *Little Rock*, Buffalo, New York
PTF 17, Buffalo, New York
USS *The Sullivans*, Buffalo, New York
MV *Commander*, Cornwall-on-Hudson, New York
USS *Growler*, New York, New York
USS *Intrepid*, New York, New York
USAT *LT-5*, Oswego, New York

Admiral's Barge, Romulus, New York

North Carolina

USS *North Carolina*, Wilmington, North Carolina

Ohio

USS *Cod*, Cleveland, Ohio

SS *William G. Mather*, Cleveland, Ohio

Oklahoma

USS *Batfish*, Muskogee, Oklahoma

Oregon

USS *Blueback*, Portland, Oregon

PT-658, Portland, Oregon

Pennsylvania

U.S. Brig *Niagara*, Erie, Pennsylvania

USS *Becuna*, Philadelphia, Pennsylvania

USS *Olympia*, Philadelphia, Pennsylvania

USS *Requin*, Pittsburgh, Pennsylvania

Rhode Island

Soviet *Juliett 484*, Providence, Rhode Island

South Carolina

USCGC *Ingham*, Mount Pleasant, South Carolina

USS *Laffey* Mount Pleasant, South Carolina

USS *Yorktown*, Mount Pleasant, South Carolina

USS *Clamagore*, Mount Pleasant, South Carolina

CSS *H. L. Hunley*, North Charleston, South Carolina

Texas

USS *Lexington*, Corpus Christi, Texas

Admiral's Barge, Fredericksburg, Texas

Japanese *HA-19*, Fredericksburg, Texas

PT 309, Fredericksburg, Texas

USS *Cavalla*, Galveston, Texas

USS *Stewart*, Galveston, Texas

USS *Texas*, LaPorte, Texas

USS *Orleck*, Orange, Texas

Virginia

- USS *Monitor*, Newport News, Virginia
- USS *Wisconsin*, Norfolk, Virginia
- RV *Aluminaut*, Richmond, Virginia

Washington

- USS *Turner Joy*, Bremerton, Washington
- RV *Deep Quest*, Keyport, Washington
- RV *Trieste II*, Keyport, Washington
- Tug *Arthur Foss*, Seattle, Washington
- Lightship *Swiftsure*, Seattle, Washington
- Schooner *Wawona*, Seattle, Washington

Wisconsin

- USS *Cobia*, Manitowoc, Wisconsin
- USCG Boat *Icelander*, Manitowoc, Wisconsin

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